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A TW0-YEAR ANALYSIS OF PRECIPITATION VARIABILITY AT THE TAR CREEK SUPERFUND SITE

Amanda J. Schroeder *, Heather R. Campbell, and Jeffrey B. Basara
Oklahoma Climatological Survey
University of Oklahoma, Norman, OK

I. INTRODUCTION

Portable automated research micrometeorological stations (PARMS) were designed and fabricated by staff at the Oklahoma Climatological Survey (OCS) to provide enhanced observations of atmospheric conditions at remote locations. Over the past three years, four PARMS were deployed at the Tar Creek Superfund site near Picher, Oklahoma to provide enhanced environmental monitoring. Because the transport of hazardous toxins through the surface water system is such a critical aspect of research and remediation at the Tar Creek Superfund Site, multiple research objectives were identified using the PARMS. These objectives include: (a) quantifying precipitation variability at the Tar Creek watershed for initialization into hydrologic models, (b) comparing radar estimated precipitation and variability with in situ observations, and (c) quantifying the spatial variability of surface observations across the watershed.

During a two-year period from 1 July 2006 through 31 July 2008, over 120 significant non-frozen rainfall events (greater than 2.5 mm) were observed by the PARMS. For each of these events, the variability of precipitation across the watershed was quantified. Further, the in situ rainfall observations were compared with quantitative precipitation estimation (QPE) products created by the National Weather Service Arkansas-Red Basin River Forecast Center (NWS ABRFC). During the summer of 2008, one of the rainfall gauges used by the ABRFC to produce the QPE products was removed from the calibration because of a significant bias. This paper will present the results of the comparison between PARMS observations and various mosaic radar data products for the two-year period and will provide insight into the unique challenges of QPE at Tar Creek before and after the gauge removal.

2. BACKGROUND

Tar Creek is located in the northeast corner of Oklahoma near the town of Picher. During the early 1900s to the late 1960s, the area was part of the Tri-State Mining District. Extensive mining produced pollutants of zinc, lead, and cadmium that caused highly acidic water to flow into streams and ponds on the surface and seep into groundwater. Mine tailings were also piled into large chat mounds over much of the area. As expected, these pollutants have adversely affected the tens of thousands of people living in the area (Gamino 1983). Figures 1 and 2 show maps of the region.

Figure 1: Location of the Tar Creek Superfund Site

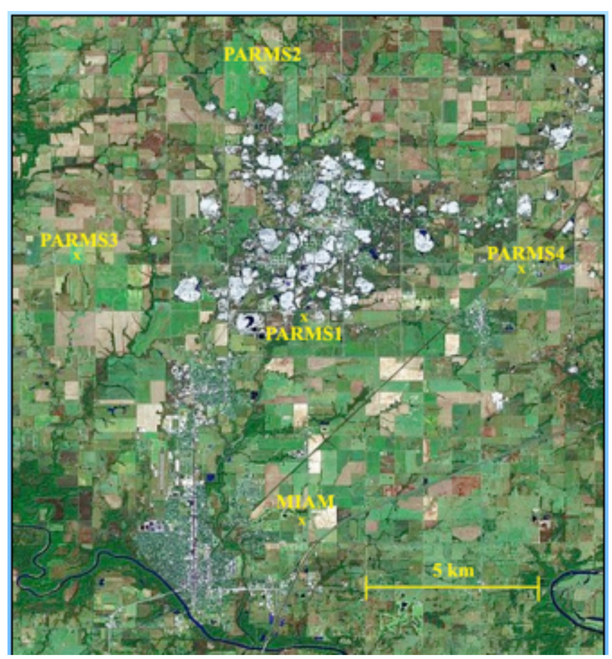

Figure 2: Location of each PARMS and the Miami Oklahoma Mesonet site (MIAM).

* *Corresponding author address*: Amanda J. Schroeder, Oklahoma Climatological Survey, 120 David L. Boren Blvd., Suite 2900, Norman, Oklahoma, 73072. E-mail: jschroeder@ou.edu

3. DATA

3.1. THE OKLAHOMA MESONET

The Oklahoma Mesonet is a research quality network of automated stations that measure a number of meteorological, hydrological, and agricultural variables. The data is collected in real time and is transmitted every 5 minutes through a radio link to the nearest terminal of the Oklahoma Law Enforcement Telecommunications System (OLETS); it is relayed to the Oklahoma Climatological Society (OCS) in Norman, OK. There are currently 120 stations placed across Oklahoma with at least one site in every county (Brock et al. 1995). Figure 3 shows the Miami Mesonet site.

Figure 3: MIAM Mesonet Site

3.2. PARMS

Portable Automated Research Micrometeorological Stations, or PARMS, are used to study atmospheric conditions at various spatial and temporal scales. One PARMS can be deployed or removed in approximately 30 minutes and transported in the back of a standard pickup truck. Each PARMS site measures air temperature, relative humidity, downwelling solar radiation, reflected solar radiation, net radiation, surface skin temperature, and the horizontal and vertical wind components (Fig. 4; OCS 2005).

Figure 4: PARMS

3.3 ABRFC PRODUCTS

The Arkansas-Red Basin River Forecast Center (ABRFC) supports the National Weather Service (NWC) with technical support for river and flood forecasts and warnings (ABRFC 2008). For the Tar Creek study, two radar products provided by the ABRFC were analyzed. The first set used was a raw radar mosaic of rainfall that had no human adjustment. In this analysis, rainfall estimates from all radars covering a given location were averaged. The second data set was a human adjusted radar mosaic. The adjusted radar mosaic is a result from a human modification of the raw radar mosaic. Both the raw radar mosaic product and the adjusted radar mosaic are created daily at 1200 UTC for the preceding 24-hour period.

4. METHODS

The first step of the analysis computed the rainfall amounts in a grid of four by four kilometer squares across the ABRFC domain (Fig. 5). The analysis was broken down 3 different ways for each radar mosaic type: 1x1 grids, 2x2 grids, and a 5x5 grid.

The raw radar mosaic and human adjusted radar mosaic products were made available by the ABRFC and created daily at 1200 UTC for the preceding 24-hour period. One of the numerous rainfall gauges used to calculate the human adjusted product was removed from the calibration by ABRFC in 2008 because it was known to grossly overestimate rainfall. Therefore, the analysis for this paper separated 2008 into two periods: before gauge removal and after gauge removal. Additionally, 6-hour analyses were also created throughout the study period and were issued at 0000, 0600, 1200 and 1800 UTC but are not discussed in the paper. The third set of data used for comparison was observations from the four PARMS and the Miami Oklahoma Mesonet site (MIAM), which were positioned to form transects across the Tar Creek Watershed. To make the comparisons easier, this data was overlaid onto the existing ABRFC four by four kilometer grid.

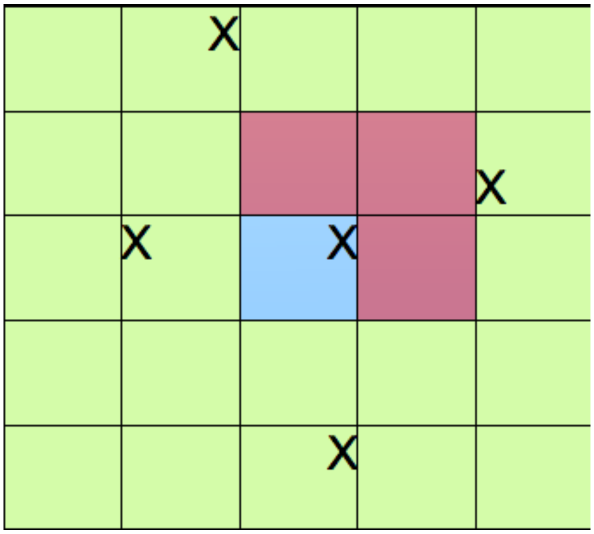

Figure 5: A visual depiction of three different rainfall estimations taken from sets of radar data. The locations of the PARMS and the Mesonet site in indicated by an "X" with the 1x1 and 2x2 grids shown for PARMS1.

5. ANALYSIS

During every significant rainfall event (>2.5 mm) in a 24-hour period, three rainfall estimations from the ABRFC products were produced: a) at single grid spaces containing a PARMS or MIAM, b) a 2X2 grid average of those squares closest to a PARMS or MIAM location, and c) a 5X5 grid product over the entire watershed. After these estimations were completed, the calculations were compared with the observed measurements from the PARMS and MIAM. The differences between the observed values and the adjusted radar mosaics and between the observed values and the raw radar mosaics were also calculated (radar value – observed value). Tables 1 – 4 show the percentages of the events that were overestimated by the radar, underestimated by the radar, had differences greater than |2.54 mm|, and had differences greater than |12.7 mm|.

For the entire 2-year period, a significant bias existed between the number of positive differences and negative differences, with the vast majority of cases being overestimated by the radar. Both the adjusted radar mosaic and the raw radar mosaic were typically overestimating the rainfall amounts. However, the raw product differences were typically slightly less biased towards overestimation as the human adjusted difference. This fact is true for all years, except for in 2008 after the errant gauge was removed from the ABRFC products. For that portion of the study period, the raw product, on average, had a higher incidence of overestimation than the adjusted product. However, only 14 rainfall events were documented during this portion of the study, and as such, the sample size was small.

Another calculation investigated the percentage of events that had the radar mosaic either overestimate or underestimate the observed value by more than 2.54 mm (0.01 in.) The results demonstrated that the raw product had a higher occurrence of events that had a difference greater than |2.54 mm| than the human adjusted product. Also, the removal of the known overestimating gauge in the ABRFC products appears to have somewhat lessened the frequency of the adjusted data over or underestimating the event by greater than 2.54 mm.

Finally, the analysis investigated how frequently a gross over or under estimation occurred by the radar mosaic (difference greater than +/- 12.7 mm, i.e. 0.5 in.). Again, the raw product had a higher frequency of over or underestimating the events, this time by at least 12.7 mm (0.5 in.). When directly comparing this category for 2008, pre and post removal, on average, a slight increase existed in the frequency of surpassing this threshold after the gauge was removed.

After reviewing all analyses, no particular site stands out as having being the most accurate when compared to the radar mosaic products. One observed outcome did indicate that the 2X2 grid cell calculations appeared to have the least occurrences of significantly over or under estimation according to the two designated thresholds of |2.54| and |12.7| mm.

6. SUMMARY

Since the summer of 2005, four PARMS have been deployed around the Tar Creek watershed. A two-year analysis to encompass both the raw and adjusted radar products has been conducted beginning in July 2006. Using the rainfall measurements from the PARMS and the MIAM Mesonet site, comparisons were made between these observed measurements and the two types of radar data provided by the ABRFC. Three estimations were calculated using a four by four kilometer grid: a) at single grid spaces containing a PARMS or MIAM, b) a 2X2 grid average of those squares closest to the PARMS or MIAM location, and c) a 5X5 grid product over the entire watershed. In June 2008, one of the gauges that was believed to consistently overestimate the adjusted radar product was removed from the calculations that create the adjusted data set for this area. Comparisons were completed between the differences in the observed measurements by the PARMS and MIAM and the radar mosaics. According to this analysis, both types of radar products continue to overestimate the rainfall amounts, even after one of the gauges was removed from the adjusted calculations. However, the adjusted product was nearly always more accurate than the raw product.

2006		% over-estimate	% under-estimate	% with difference > |2.54 mm|	% with difference > |12.7 mm|
adj	P1 1x1	70	22	48	13
adj	P1 2x2	83	17	52	9
adj	P1 5x5	74	26	48	13
adj	P2 1x1	83	13	48	4
adj	P2 2x2	78	9	43	4
adj	P2 5x5	78	13	52	0
adj	P3 1x1	87	4	43	13
adj	P3 2x2	74	17	39	13
adj	P3 5x5	74	22	35	4
adj	P4 1x1	61	30	30	4
adj	P4 2x2	70	26	39	9
adj	P4 5x5	70	30	52	9
adj	MIAM 1x1	57	39	26	9
adj	MIAM 2x2	57	35	17	4
adj	MIAM 5x5	65	30	61	4
	average	**71.88**	**22.32**	**42.32**	**7.54**
raw	P1 1x1	65	35	57	17
raw	P1 2x2	65	35	61	13
raw	P1 5x5	61	39	43	17
raw	P2 1x1	52	35	52	9
raw	P2 2x2	52	43	22	9
raw	P2 5x5	65	35	61	13
raw	P3 1x1	43	52	52	9
raw	P3 2x2	43	48	43	9
raw	P3 5x5	52	43	70	9
raw	P4 1x1	57	43	48	13
raw	P4 2x2	57	43	57	13
raw	P4 5x5	52	48	57	4
raw	MIAM 1x1	43	57	35	0
raw	MIAM 2x2	48	52	30	0
raw	MIAM 5x5	52	48	52	4
	average	**53.91**	**43.77**	**49.28**	**9.28**

Table 1: Percentages for events in 2006.

2007		% over-estimate	% under-estimate	% with difference > |2.54 mm|	% with difference > |12.7 mm|
adj	P1 1x1	70	22	61	17
adj	P1 2x2	76	19	50	13
adj	P1 5x5	76	22	63	11
adj	P2 1x1	67	29	56	15
adj	P2 2x2	65	31	50	15
adj	P2 5x5	65	33	60	15
adj	P3 1x1	67	31	57	17
adj	P3 2x2	72	26	54	11
adj	P3 5x5	65	35	65	15
adj	P4 1x1	62	35	62	31
adj	P4 2x2	65	27	65	23
adj	P4 5x5	65	35	73	23
adj	MIAM 1x1	54	46	65	15
adj	MIAM 2x2	57	43	56	7
adj	MIAM 5x5	48	52	52	7
	average	**65.04**	**32.32**	**59.17**	**15.74**
raw	P1 1x1	65	33	72	22
raw	P1 2x2	69	31	74	15
raw	P1 5x5	69	31	76	19
raw	P2 1x1	54	40	69	17
raw	P2 2x2	60	38	71	21
raw	P2 5x5	60	40	79	23
raw	P3 1x1	54	44	69	26
raw	P3 2x2	57	43	80	24
raw	P3 5x5	56	41	85	26
raw	P4 1x1	58	42	69	19
raw	P4 2x2	54	46	73	27
raw	P4 5x5	54	38	69	23
raw	MIAM 1x1	54	46	74	19
raw	MIAM 2x2	52	43	67	13
raw	MIAM 5x5	52	46	76	22
	average	**57.63**	**40.36**	**73.53**	**21.06**

Table 2: Percentages for events in 2007.

2008 - pre gauge removal		% over-estimate	% under-estimate	% with difference > |2.54 mm|	% with difference > |12.7 mm|
adj	P1 1x1	73	23	53	13
adj	P1 2x2	73	23	50	10
adj	P1 5x5	70	23	57	10
adj	P2 1x1	84	13	53	16
adj	P2 2x2	78	13	53	13
adj	P2 5x5	75	25	63	13
adj	P3 1x1	75	19	59	16
adj	P3 2x2	75	19	44	16
adj	P3 5x5	72	28	59	3
adj	P4 1x1	78	22	44	16
adj	P4 2x2	78	19	59	9
adj	P4 5x5	81	19	59	13
adj	MIAM 1x1	69	31	59	6
adj	MIAM 2x2	72	22	50	6
adj	MIAM 5x5	78	16	63	16
	average	**75.49**	**20.92**	**55.04**	**11.60**
raw	P1 1x1	70	17	60	20
raw	P1 2x2	73	23	53	20
raw	P1 5x5	73	27	63	17
raw	P2 1x1	81	16	69	13
raw	P2 2x2	78	22	63	16
raw	P2 5x5	81	16	63	16
raw	P3 1x1	72	28	81	19
raw	P3 2x2	69	31	69	22
raw	P3 5x5	63	34	63	25
raw	P4 1x1	88	13	56	13
raw	P4 2x2	88	13	66	9
raw	P4 5x5	75	25	69	16
raw	MIAM 1x1	63	28	53	22
raw	MIAM 2x2	72	25	59	16
raw	MIAM 5x5	78	16	66	22
	average	**74.86**	**22.15**	**63.44**	**17.53**

Table 3: Percentages for the events in 2008 prior to the removal of a rain gauge known to contribute to the overestimation by the adjusted radar mosaic product.

2008 - post gauge removal		% over-estimate	% under-estimate	% with difference > |2.54 mm|	% with difference > |12.7 mm|
adj	P1 1x1	79	21	57	7
adj	P1 2x2	86	14	64	14
adj	P1 5x5	71	21	50	21
adj	P2 1x1	79	21	50	29
adj	P2 2x2	86	14	50	7
adj	P2 5x5	79	21	71	21
adj	P3 1x1	79	21	57	7
adj	P3 2x2	79	21	57	7
adj	P3 5x5	64	36	36	21
adj	P4 1x1	71	29	43	14
adj	P4 2x2	71	29	71	14
adj	P4 5x5	86	14	57	29
adj	MIAM 1x1	86	14	57	21
adj	MIAM 2x2	79	14	50	14
adj	MIAM 5x5	79	21	50	14
	average	**78.10**	**20.95**	**54.76**	**16.19**
raw	P1 1x1	86	14	71	21
raw	P1 2x2	93	7	79	14
raw	P1 5x5	93	7	71	14
raw	P2 1x1	93	7	71	29
raw	P2 2x2	100	0	64	14
raw	P2 5x5	86	14	86	21
raw	P3 1x1	86	14	71	14
raw	P3 2x2	86	21	64	14
raw	P3 5x5	79	21	79	21
raw	P4 1x1	86	7	64	14
raw	P4 2x2	86	14	71	21
raw	P4 5x5	93	7	79	21
raw	MIAM 1x1	79	14	71	14
raw	MIAM 2x2	86	14	71	14
raw	MIAM 5x5	79	21	64	29
	average	**87.14**	**12.38**	**71.90**	**18.57**

Table 4: Percentages for the events in 2008 after the removal of a rain gauge known to contribute to the overestimation by the adjusted radar mosaic product.

The number of significant over or under estimations by the adjusted product (i.e. number of days where over or under estimation exceeded 2.54 mm) appears to be slightly improved, but gross over or underestimations of at least 12.7 mm became more frequent. Also, the 2X2 grid cell calculations had, on average, the fewest events to be overestimated by 2.54 mm, and no particular site appeared to be more accurate than the others. Further study is needed in order to gain a better understanding of the specifics behind these findings.

7. REFERENCES

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