9.2 COMPARISON OF EXTREME RAINFALL FREQUENCY IN LUBBOCK, TEXAS USING GAUGE AND RADAR DATA

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1. INTRODUCTION

Precipitation return periods are used for a variety of city planning purposes – wastewater infrastructure and floodplain management in particular. An accurate estimate of heavy precipitation frequency is important when determining money and resources for dealing with these often disruptive events. Due to the localized nature of thunderstorm precipitation in the West Texas region, heavy precipitation events that occur within the City of Lubbock often are not recorded by the Automated Surface Observing System (ASOS) rain gauge located at Lubbock International Airport despite causing significant impacts within the City of Lubbock. As a result, it is possible that the airport rain gauge data does not provide a complete picture of the actual frequency of heavy rain events in the City of Lubbock.

In this study, an analysis of the 10-, 50-, and 100-year return period for daily precipitation amounts will be completed using two data sources, the traditional rain gauge data approach and Next Generation Doppler Radar (NEXRAD) data, which has better spatial resolution. It is anticipated that using radar data to determine the heavy rainfall return periods will provide a more accurate picture of the heavy rainfall climatology for the region.

2. PREVIOUS WORK

Because of its excellent spatial resolution, there is much ongoing research in the area of using radar data to estimate precipitation totals. A hydrologic study of the Upper Guadalupe River Basin (Wang et al., 2013) found the best agreement between radar estimated and gauge rain totals at a range of 50-150 km from the radar, with an increase in error both above and below that range. For short temporal periods and appropriate ranges, they found radar to provide a good estimate of rain rates in real time, with potential application to flash flood forecasting and monitoring. Wright et al. (2014) used the stochastic storm transportation (SST) technique to create a robust radar data set for the Charlotte, North Carolina metropolitan area that they then used in a model developed for watershed management applications. Wright et al. used a high resolution radar dataset from the Hydro-NEXRAD processing system, which is designed specifically for hydrologic studies.

A number of studies have used rain gauge data to document an increase in heavy and extreme precipitation events in the United States (i.e. Groisman et al., 2004; Villarini et al., 2013). Groisman et al. (2005) and Karl and Knight (1998), found a disproportionate increase in extreme precipitation events, in contrast to moderate precipitation events. Villarini et al. went on to report an increase in the frequency, but not the magnitude of extreme precipitation events, as defined by the maximum one-day precipitation total. Allan and Soden (2008) observed a significant increase in heavy and very heavy precipitation in a warming climate. Additionally, they also noted that climate models consistently underestimate the magnitude of the increase in heavy and very heavy precipitation. Karl and Knight (1998) found that more than 50% of the increase in precipitation projected in a warming climate could be attributed to the upper 10% of events, meaning heavy and very heavy rain events represent most of the projected increase in precipitation.

3. DATA

Archived rain gauge data recorded at the Automated Surface Observing System (ASOS) station situated at the Lubbock International Airport were obtained for the study period from the National Climatic Data Center (NCDC). The study period was chosen to be the ten year period beginning in 2004, due to the limited availability of the radar data. The National Weather Service (NWS) radar located at the Lubbock International Airport (KLBB) was chosen for the radar portion of the study due to its proximity to the study area, the City of Lubbock puts most parts of the city within 10-20 km of the radar. Other radars considered were located in Midland and Amarillo, TX which are both approximately 200 km from the City of Lubbock. A detailed report on using radar data

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for precipitation estimation (NWS, 1994) specifies that precipitation estimates are best within 110 km of the radar. Radar data were also obtained from the NCDC. Due to the large volume of radar data required, an automated utility was developed using LabVIEW. The radar product chosen for this analysis was the NEXRAD Level III 1-hour precipitation estimate. More information about that product is available in Hunter (2004). The precipitation estimate from the first scan in each hour were used to obtain a radar estimated rain total for each calendar day.

4. METHOD

A peak-over-threshold technique (Acero et al., 2011; Reiss and Thomas, 1991) was used to evaluate the 24-hour rain accumulations. The peak-over-threshold technique was chosen in favor of the block maxima method because it is anticipated that more than one heavy rainfall event will have occurred in a given year. The threshold (u) chosen for the analysis was the 95th percentile 24-hour precipitation total for the distribution of all non-zero rainfall days in the record. Days with a 24-hour rain total greater than the 95th percentile were considered heavy rainfall events. In the ten-year rain gauge record from 2003-2013 there were a total of 1990 heavy rain days. The gauge record was subjected to a declustering algorithm found in the in2extRemes software package (Gilleland and Katz, 2011) to ensure independence of heavy rain events. A Generalized Pareto (GPD) distribution was then fitted to the declustered exceedance data. The shape (ε) and scale ($\sigma(t)$) parameters estimated from those fits were used to compute a curve of return period (N) 24-hour rainfall totals (x_N) using the equation found in Acero et al. (2001).

$$x_N = u + \frac{\sigma(t)}{\varepsilon}\left[\left(Nn\xi_u\theta\right)^{\varepsilon} - 1\right]$$

where:

n = number of observations per season
ξ_u= probability of exceedance of u(t), and
θ = extremal index

The second step of the analysis was to evaluate daily rainrates using archived NEXRAD data from the NCDC. Level III 1-hour precipitation estimates observed by the KLBB (Lubbock, TX) radar were used to compute 24-hour radar-estimated rain totals. Because the 1-hour precipitation total product runs continuously (i.e. an estimated precipitation total is created for each pixel in each 5-minute scan) the 24-hour total precipitation estimate was computed by summing the estimates for the first image in each hour. 24-hour radar generated precipitation estimates were computed at the midpoints of a 1 km grid covering City of Lubbock. A peak 24-hour rain total was then chosen for each day from all of the grid cells. The radar-derived 24-hour rain total record began January 1, 2004, which is when the Level III 1-hour precipitation product became available, and ends December 31, 2014. The availability of Level III radar data limits the study to that eleven year period. The effect of that limitation is discussed in the next section.

5. RESULTS AND DISCUSSION

Due to the limited timescale of the radar data, return period curves for ten year periods of gauge data were compared with the return period curve for the entire gauge dataset in order to examine the effect of the short timescale on the return period curves. The return period curves for sequential decades of gauge data beginning in 1948 (Figure 1) indicate significant uncertainty for return periods calculated with ten years of data. The curve generated using the complete dataset (1948-present) falls closer to the expected values based upon the National Weather Service (NWS) Rainfall Frequency Atlas of the United States (National Weather Service, 1961), namely a 100-year return period 24-hour accumulation rain total of approximately 178 mm/194 mm for the NWS/current study value. Table 1 lists the return periods for both the gauge data and the National Weather Service (NWS) data.

Table 1. 24-hour precipitation accumulations for three return periods for the Lubbock Airport rain gauge record (1948-present) and the official values from the NWS Rainfall Frequency Atlas of the United States.

Return Period (years)	NWS (mm)	Gauge Data (mm)
10	115	125
50	150	170
100	180	194

Finally, a three-month period of 24-hour radar rain total estimates (March, April, and May

2009) was generated for a single pixel collocated with a rain gauge operated by the Texas Tech Mesonet (Schroeder et al., 2005) at Reese Center, located west of Lubbock, Texas. Time histories from that period (Figure 2) show mixed agreement between the two time histories with some notable discrepancies, particularly the 64 mm rain event near the middle of the record that was undetected in the radar record. More investigation is needed to understand these inconsistencies.

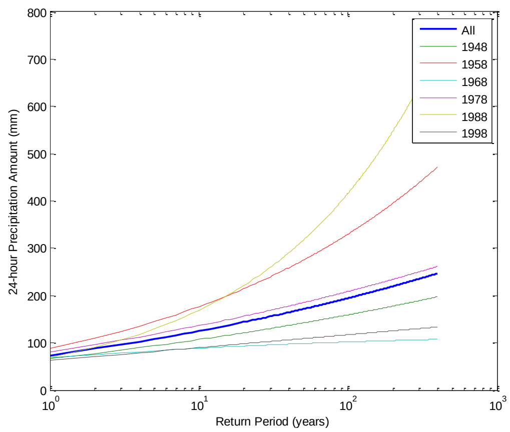

Figure 1. Return period curves based upon a fit of the GPD to individual decades of LBB gauge data. Decade begins in year indicated on legend. Blue curve represents data for entire period 1948-present.

Time histories of the radar and gauge data for the complete study period and study area (Figures 3A and 3B) also reveal considerable differences. Although it was anticipated that some differences would exist between the two records, the magnitude of the difference and the appearance of the radar time history (for example, the absence of zero rain total days in the second half of the record), suggests that there may be a problem with the radar data acquisition method used. Highlighting the large differences in appearance between the gauge and radar data are the 95th percentile thresholds computed for the two datasets, which were 29.3 mm for the gauge and 64.8 mm for the radar data. There were also large differences in the resulting 100-year 24-hour precipitation total, with 179 mm for the radar record and 377 mm for the gauge.

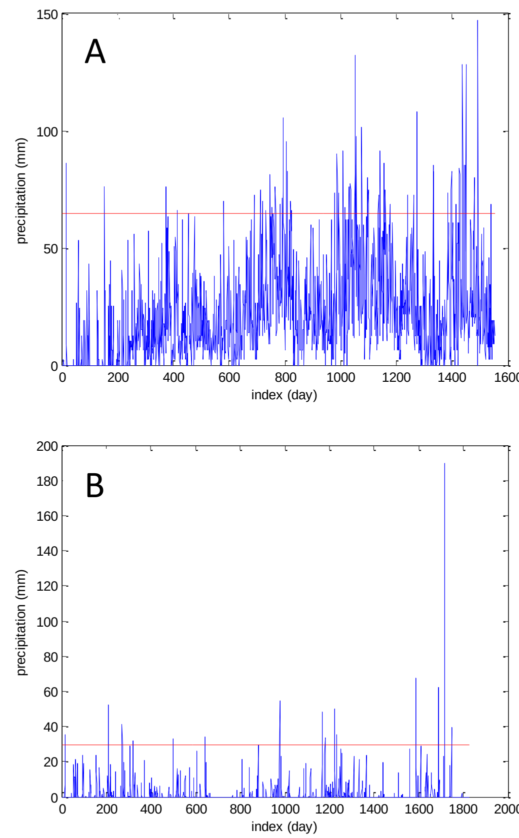

Figure 3. Time histories for the radar (A) and gauge (B) 24-hour rain totals. 95th percentile indicated by red line.

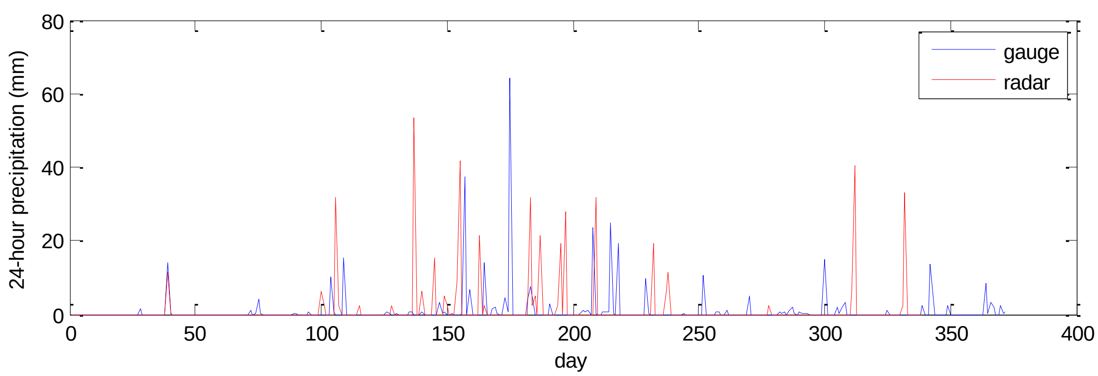

Figure 2. Time histories of radar-estimated and measured by rain gauge 24-hour rainfall totals for Reese Center, west of Lubbock, TX.

The differences in 100-year 24-hour rain totals are confirmed by the return period curves for the radar and gauge data, provided in Figure 4. The difference in appearance between these two curves is similar to the differences observed between the other short-duration return period curves in Figure 1. Between this uncertainty and the unusual appearance of the second half of the radar time history, it cannot be said at this time that the differences observed in the return period curves is based upon a fundamental difference in heavy rain distribution observed by gauge versus radar data.

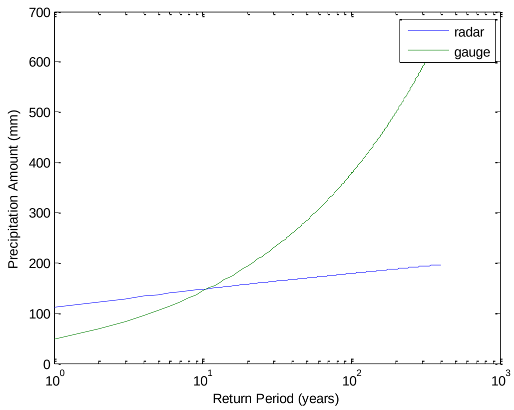

Figure 1 Return period curves for the study period 1/2004-12/2014 for the radar estimated and gauge 24-hour rain totals

6. FUTURE WORK

Time histories of gauge and radar estimated 24-hour precipitation totals were subjected to the peaks-over-threshold method for analyzing extreme data. A GPD was fitted to the exceedance data and the resulting scale and shape parameters were used to generate return period curves for the radar and gauge datasets. The next steps for this analysis are as follows:

- Improve radar data acquisition technique. Find source of error in second half of record.
- Identify several case studies of heavy rain events in the City of Lubbock and investigate how the radar handles precipitation totals with these events.
- Increase the study period temporally by finding a new source of radar data or by applying a technique like stochastic storm transposition (Wright, 2014) that allows for a more robust dataset in situations in which the data record is limited temporally.

6. REFERENCES

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