1.11

DEPTH-URATION FREQUENCY FOR PRECIPITATOIN USING THE OKLAHOMA MESONET

Andrew J. Reader
Oklahoma Climatological Survey, Norman, OK

1. Introduction

The information contained within a study of duration and frequency of precipitation study has many uses throughout society today. Often referred to as depth-duration frequency of precipitation, this information is critical for controlling local rainfall runoff. Depth-duration frequency of precipitation can be defined as the amount of precipitation that accumulates over a time period and how often that amount is recorded. Tortorelli et al. (1998) explained that the depth-duration frequency of precipitation is taken into account in the design of drainage structures for storm drains on roadways, parking lots and culverts. Depth-duration frequency information also is useful for rainfall-runoff models. This information is crucial for designing safe structures in flood prone areas. The current study builds upon previous work by the United States Geological Survey by taking advantage of a new data set provided by the Oklahoma Mesonet. As a result a more complete understanding is possible of the depth-duration frequency of precipitation in the state of Oklahoma.

The convective nature of rainfall in Oklahoma lends to highly variable rainfall rates. By using the fine spatial density of gauges in the Oklahoma Mesonet, a more complete depth-duration frequency of precipitation can be produced. This dense network may record locally heavy, small-scale rainfall events. Having records of these small-scale rainfall events also will provide more detailed information for rainfall-runoff models used by hydrologists. With the ability to record more small-scale rainfall events, the Mesonet will aid in creating a more complete depth-duration frequency of precipitation for Oklahoma.

2. Data Source and Editing

Rainfall measurements with a temporal resolution of 5-minutes were acquired by the Oklahoma Mesonetwork (Mesonet). The Mesonet, developed through a partnership between the University of Oklahoma and Oklahoma State University, is a permanent automated mesoscale observation network (Brock et al. 1995). The Mesonet consist of 116 stations (Fig. 1) measuring 13 atmospheric and subsurface variables. Measurements are recorded at 5-minute intervals for each site, producing 288 observations of each of the 13 parameters per day.

Data collected by the Mesonet undergoes rigorous quality assurance (QA) procedures. The QA system compiles information from four analysis procedures: laboratory calibration and testing, on-site intercomparisons, automated routines, and manual inspection (Shafer et al. 2000). The QA system is set up to flag “questionable” data should the data fail any of the QA’s routines.

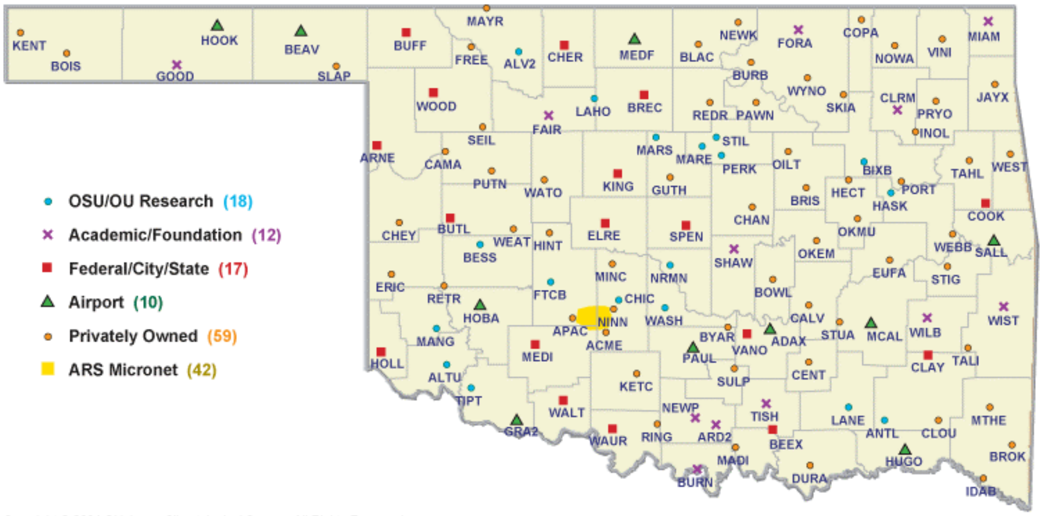
Even after precipitation measurements go through the extensive QA routines, errors may still exist in the data. To uncover more suspect data in the measurements, a double mass analysis and a time series analysis of the data were performed. The double mass and time series analysis was completed for every station within the Oklahoma Mesonet from 1994 through 2003. In all, over 100 million observations were reviewed using the double mass and time series analysis. As a result, over 145,000 observations were determined to be “bad”, and were removed from the data set. This additional QA step added to the already extensive QA procedures that Mesonet data undergoes. These steps ensure that the Mesonet provides the highest quality data for researchers worldwide.

3. Methods and Analysis

Accumulations at rainfall intervals of 15, 30, 45, 60 and 90-minutes were calculated along with 2-hour, 3-hour, 6-hour, 12-hour and 24-hour rainfall totals. Because the data have a temporal resolution of

---

Corresponding author address: Andrew J. Reader, Oklahoma Climatological Survey, 100 E. Boyd St., Suite 1210, Norman, OK 73019. Email: areader@mesonet.org



Copyright © 2004 Oklahoma Climatological Survey. All Rights Reserved.

Figure 1. Map of Oklahoma Mesonet sites

5-minutes, 5-minute totals were readily available. For example, in the case of a 15-minutes total, one total would span the period from 8:00 a.m. to 8:15 a.m. The next 15-minute total would span from 8:05 a.m. to 8:20 a.m., and so on.

Once the different rainfall interval totals were obtained for each Mesonet site, the data were fit to a distribution. The maximum 2-year, 5-year, 10-year, 25-year, 50-year and 100-year rainfall return periods were determined from the modeled distribution. Because the steps taken in this study closely follow the USGS study the generalized logistic and the generalized extreme-value distributions were used.

As in the USGS study by Tortorelli et al. (1998), L-moments were utilized. Hosking (1990) defines L-moments as expectations of certain linear combinations of ordered statistics. These L-moments can be defined for any random variable, in this case rainfall. With this variable, a mean must exist and form the basis of a general theory that covers the summarization and description of theoretical probability distributions, the summarization and description of observed data samples, estimation of parameters and quantiles of probability distributions, and hypothesis tests for probability distributions. The theory of L-moments will parallel the theory of probability weighted moments (PWM) in this study.

L-moments are used because they are linear functions of the data, and as such they suffer less from the effects of sampling variability. L-moments are also used in this study because sample L-moments are unbiased. Bias is a large source of error when using probability weighted moments. Probability weighted moments weigh all observations equally, which creates the bias in the shape of the distribution. Most of the biases are found in the extreme tails of distributions (Hosking et al. 1985). L-moments weigh the larger rainfall values more heavily, which gives a more accurate depiction of the extreme tails of a distribution. More accurate results can be obtained, even with small sample sizes, when using L-moments. L-moment ratios are not unbiased, but the biases are very small with large sample sizes. The sample sizes used in this study are of the order 10^4 for the smallest samples. L-moments have been used in similar studies, and have produced adequate results.

4. Results

The resulting output from this study is a depth-duration frequency of precipitation for the state of Oklahoma. Contour plots were created for the 2-year, 5-year, 10-year, 25-year, 50-year and 100-year return period for each of the afrementioned rainfall time intervals. Each return period for each time interval has been plotted individually using the Wxscope plug-in software (Wolfinbarger et al. 2002). The Wxscope plug-in is software created by the Oklahoma Climatological Survey that allows weather data to be visualized in a format designated by the user. This plug-in has the capability of contouring site-specific rainfall measurements.

All stations with a length of record of at least eight years were plotted with the exception of the Cheyenne (CHEY) station. All stations with shorter lengths of record were kept out of the

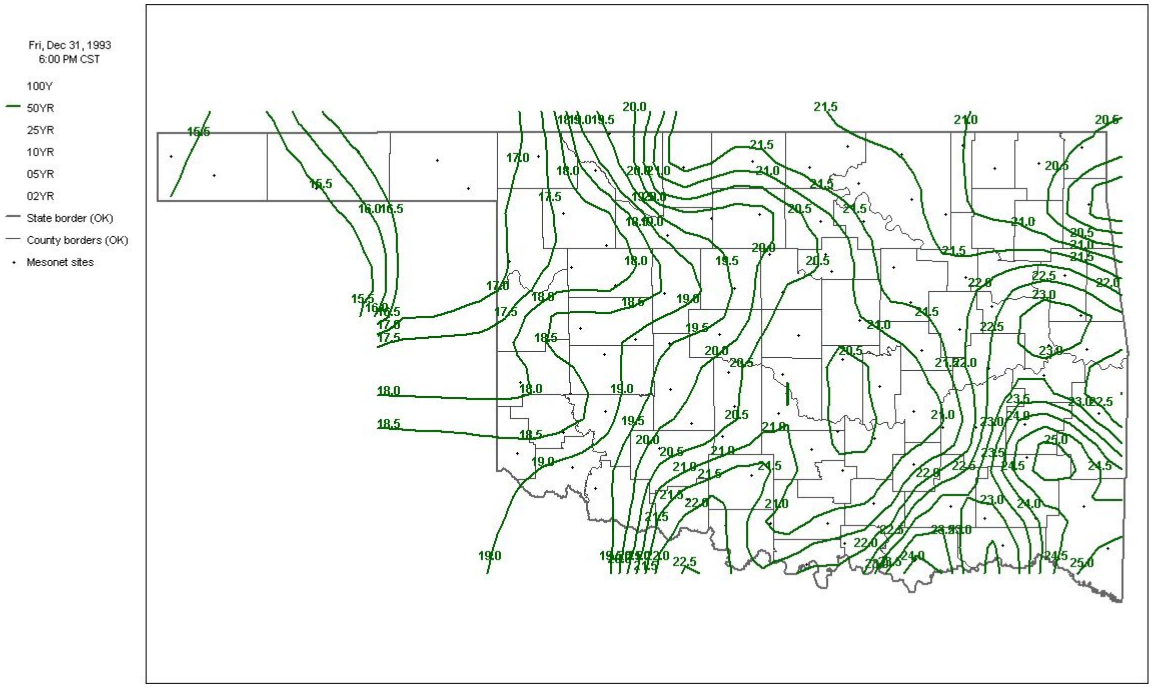


Figure 2. 3-hr, 50year rainfall contour map. Tightly packed contours in western Oklahoma may be evidence of the effects the dryline has on rainfall distribution.

contouring. The CHEY station was left out due to a very heavy rainfall event that skewed the model output. The CHEY site received 9.81 inches of rainfall in June of 1996. This single rainfall event creates an erroneous rainfall maximum over the CHEY site in the contour plots. Stations that did not have a sufficient data record were also left due to the errors they create. Sites with shorter records tend to create misleading rainfall minima over the sites. Section 5 will further discuss the effects these stations have on the output.

The intervals of the contours have been selected arbitrarily to give the most detail, without cluttering the maps. The values of the contours are in millimeters and the contour intervals range from 0.1 millimeters upwards to 3.0 millimeters depending on the time interval and return period.

The modeled output provides some interesting characteristics of rainfall across Oklahoma. The contours for all time intervals and all return periods are consistent. Lower rainfall totals exist in the northwestern portions of the state and increase across the state towards the southeast. In almost all cases, rainfall minima exist in the Oklahoma panhandle and rainfall maxima exist in the southeast corner of the state. This is not unexpected. Moisture availability in the panhandle is very limited, where as in the southeast, moisture is quite abundant. This would be one reason for the location of such minima and maxima.

The contours for the shorter time periods exhibit a more random nature than the longer time periods. This is not unexpected, as rainfall for these short periods can be erratic due to the convective nature of rainfall events in Oklahoma. As the time periods get longer, a more organized rainfall pattern begins to materialize. The longer time periods exhibit the northwest to southeast gradient of rainfall values. With the longer time periods, the randomness of rainfall values becomes less and less. This can be shown by the L-skew parameter used in the shape functions of the GEV distribution

One of the most interesting features of these plots is the rainfall gradient that occurs in the western one-third of the state. This gradient may be a result of the dryline feature that is typically located in this part of the state in the spring months. This boundary is where convection typically forms and east of this boundary, heavy rainfall from these storms can occur, while west of the boundary remains very dry, driving this gradient in western Oklahoma. Figure 2 illustrates this gradient. Since this data set only covers the last ten years, it is conceivable that the gradient may shift in position when a longer data set is added to the study due to changes in rainfall patterns over longer periods of time.

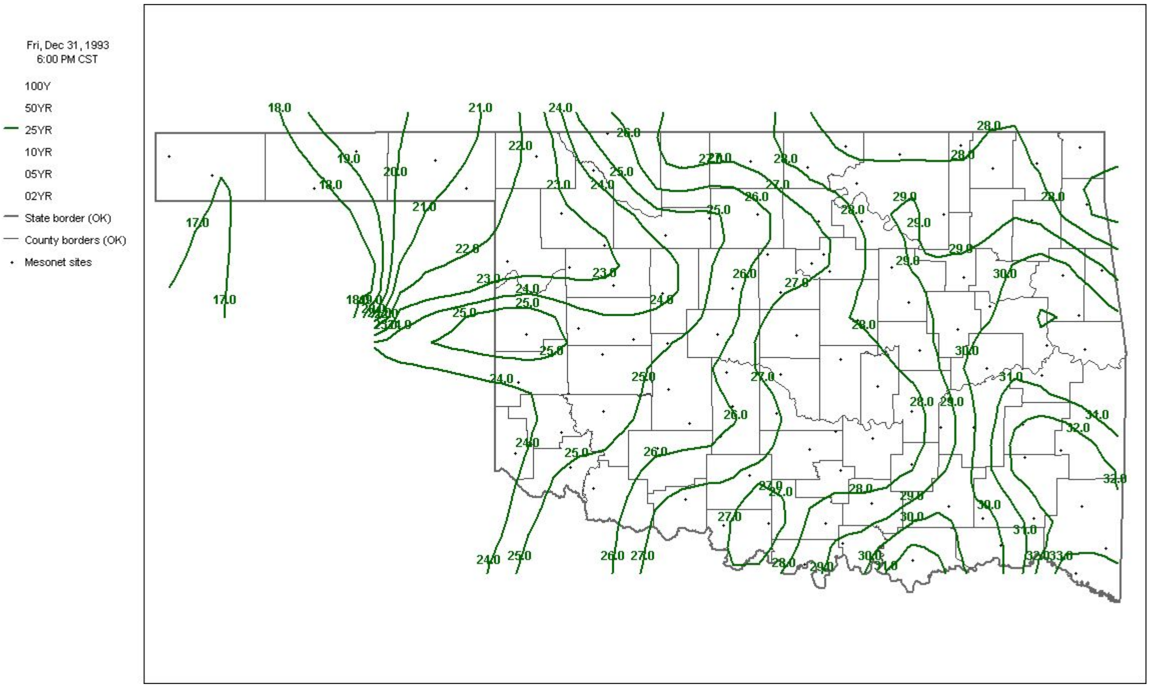


Figure 3. 6-hr, 25year rainfall contour map: Note the rainfall maximum in western Oklahoma.

5. Effects of an Individual Rain Event

Along with the length of record, individual rainfall events can create flawed output for a depth-duration frequency of precipitation study. A single rainfall event can create a misleading rainfall maximum in the contour plot. This is the case for the Cheyenne (CHEY) site in western Oklahoma. On 14 June 1996, the Cheyenne site received 9.81 inches of rain in a 24-hour period. All neighboring sites received less than one inch of rain for the same time period. Extensive data QA was run on this day to ensure that the rainfall amount was accurate. The QA has deemed the data to be accurate, and therefore a single station received close to ten inches of rain.

In Figure 3, there is a rainfall maximum centered over the Cheyenne station in west central Oklahoma. As a result of this individual event, the Cheyenne station has been left out of the analysis. By removing the station, a more consistent contour map is created and without the rainfall maximum in western Oklahoma. This illustrates how sensitive the depth-duration frequency of precipitation output can be to very small-scale isolated rain events.

The impact a single convective rainfall event can have on the output of a depth-duration frequency study highlights the importance of understanding the characteristics of the data set that is being used. As rainfall networks become denser in time, it is likely that more convective events will be observed. It will be up to the user of the data set to understand and correctly interpret any results from a depth-duration frequency of precipitation study.

6. Further Research

There are numerous ways in which this research can be improved upon in the future. Not all aspects of the depth-duration frequency study could be looked at due to time constraints. First and foremost, a number of distribution models should be tested to improve upon the rainfall contours. This study only looked at two models, GLO and the GEV. More model testing, through goodness-of-fit measures, should be done to find the best model fit to the data set.

This study utilized the temporal resolution of the Oklahoma Mesonet. Interval values were calculated every five minutes, as explained in section 2. In order to more accurately compare this study to other studies such as the USGS study from Tortorelli et al. (1998), rainfall measurements can be taken hourly or daily. The USGS study used a combination of 15-minute data, hourly data and daily rainfall data to produce their depth-duration frequency maps. Mesonet data can be used in the same manner to obtain rainfall values for intervals similar to the USGS study.

Finally, multiple data sets need to be merged to make the most complete depth-duration frequency rainfall of Oklahoma. A combination of Mesonet data along with the data set used by the USGS would produce the most accurate results. As the data sets grow larger, more information can be put through the different distribution models to create the most accurate frequency maps possible.

7. Conclusion

The purpose of this study was to build a depth-duration frequency of precipitation for the state of Oklahoma. The steps taken in this study mirrored the USGS study done by Tortorelli et al. (1998), but used a new data set. The Oklahoma Mesonet provided a data set of 116 automated stations, yielding 10 years of 5-minute rainfall data over a denser network of gauges than the USGS. This study investigated rainfall intervals of 15, 30, 45, 60, 90 minutes as well as 2, 3, 6, 12 and 24 hours. For each interval, recurrence intervals of 2, 5, 10, 25, 50, and 100 years were calculated. The data used in these intervals underwent vigorous QA testing, double mass analysis and time series analysis to ensure that the data was as reliable as possible.

The results from this study were mixed. The rainfall values estimated by the generalized extreme value distribution were very low in comparison to the USGS study by Tortorelli et al. (1998). The reason for this can be traced back to the length of data record. A data set with a longer record would help to bring these values closer to the USGS study. The Mesonet data set has only ten years of data, where as the USGS study had close to 40 years worth of data. Even though the values were not close in the two studies, the rainfall patterns were very similar. This study showed increasing rainfall amounts from the northwest to the southeast of the state, which is consistent with the mirrored USGS study.

Another valuable result from this study is the influence of intense small-scale rain events. The station in Cheyenne, which received close to ten inches of rainfall on 14 July 1996, is an example of how a single event can affect the depth-duration frequency plots. Closer inspection and interpretation is necessary to correctly assess the rainfall patterns contoured in depth-duration frequency studies.

This depth-duration frequency of precipitation study yielded some interesting results and showed how length of record can affect accuracy. Although the recurrence values were low, this study shows that the Oklahoma Mesonet can be used to effectively visualize rainfall patterns across the state. As the Mesonet data set continues to mature, it will become a more useful tool in computing accurate depth-duration frequency values of precipitation for the state of Oklahoma.

REFERENCES

Brock, F. V., K. C. Crawford, R. L. Elliott, G. W. Cuperus, S. J. Stadler, H. L. Johnson and M. D. Eilts. 1995. The Oklahoma Mesonet: A Technical Overview. *Journal of Atmospheric and Oceanic Technology*, **12**, 5-19

Hosking, J.R.M., 1990: L-Moments- Analysis and estimation of distributions: Using linear combinations of ordered statistics: Journal Royal Statistical Society B, v. 52, no. 1, p. 105-124.

Hosking, J. R. M., J.R. Wallis, and E. F. Wood, 1985 : Estimation of the generalized extreme-value distribution by the method of probability-weighted moments. Technometrics 27 251 261. Z . NERC 1975 . Flood Studies Report 1. Natural
Environment Research Council, London. Z .

Shafer, M. A., C. A. Fiebrich, D. Arndt, S. E. Fredrickson, and T. W. Hughes, 2000: Quality assurance procedures in the Oklahoma Mesonetwork. *Journal of Atmos. and Oceanic Tech.*, **17**, 474-494.

Tortorelli, R.L., A. Rea, , and W. H. Asquith, 1998: Depth-duration frequency of precipitation for Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 99-4232, 133p.

Wolfinbarger, J.M., J.R. Greenfield, T.B. Stanley, and R.A. Young. 2002. WeatherScope: Interactive Software for Visualizing Web-Based Meteorological Data Sets. Preprints, 18th International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology; American Meteorological Society, Orlando, Florida, January 13-17.