J3.14

MAXIMUM WIND GUST RETURN PERIODS FOR OKLAHOMA USING THE OKLAHOMA MESONET

Andrew J. Reader
Oklahoma Climatological Survey, Norman, OK

1. Introduction

It is well known that Oklahoma experiences convective events throughout the year, and these storms produce numerous severe wind gusts. However, severe wind events are also produced during non-convective days. During the past fourteen years, many of these severe gusts have been recorded by the Oklahoma Mesonet. Improved knowledge of the frequency and severity of these events are important to many in Oklahoma. Wind gust information is critical to structural engineers, as well as wind energy producers - wind energy is a booming industry across the western half of the state. Improved knowledge of wind gust frequency is also helpful to weather forecasters and the public, to help put wind events in perspective. This study determines the frequency of high-end severe wind gust events across the state using the Oklahoma Mesonet.

The Oklahoma Mesonet provides a network of 116 automated weather stations across the state, and daily maximum wind gust values were used from each site. The study fits wind data to a Weibull distribution, which is most often used in atmospheric sciences for modeling wind data (Wilks 1995), and incorporates the use of probability weighted linearized moments, or L-Moments, in the calculations. These tools combined help to produce data that can improve the understanding of the frequency and severity of high-end wind events across Oklahoma.

Corresponding Author Address: Andrew J. Reader, Oklahoma Climatological Survey, 120 David L. Boren Blvd. Suite 2900, Norman, OK 73072. Email: areader@mesonet.org

2. Data Source

Daily maximum wind gust data were acquired from 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 22 atmospheric and subsurface variables. Measurements are recorded at 5-minute intervals for each site, producing 288 observations of each of the 22 parameters per day. The 5-minute wind measurements from the Mesonet are an average of 3-second measurements within that 5-minute period. The maximum 3-second observation is the wind gust for that 5-minute observation period. The data used in this study are the maximum 3-second wind speed recorded for a 24-hour period for each of the 116 sites across the state.

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. Any data that were deemed questionable were not used in this study.

3. Methods and Analysis

Daily maximum wind gusts from 1994-2003 were obtained for 108 Mesonet sites. The wind gust values for each site w ere ordered, from lowest value to highest value, and ranked in ascending order. Once ordered, the wind gust values were fit to a Weibull distribution using L-moments.

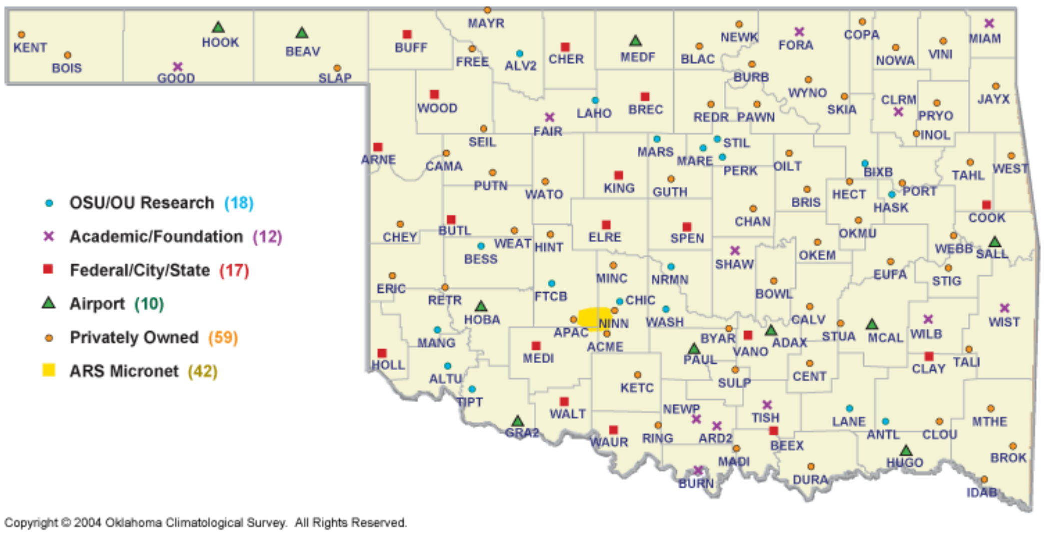

Figure 1. Map of Oklahoma Mesonet sites

The maximum 2-year, 5-year, 10-year, 25-year, 50-year and 100-year maximum wind gust return periods were determined from the modeled distributions.

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 daily wind gust maxima. 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 (Hosking and Wallace 1997). 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 wind gust 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 (Hosking and Wallace 1997). L-moments have been used in similar studies, and have produced adequate results (Tortorelli et al 1998).

A goodness of fit (Z-score) measure was conducted on the Weibull distribution for this data set. The computed shape parameters of the distribution were averaged for all the sites and used as a single region for the goodness of fit test. This follows the methods of Hosking and Wallace (1997). A distribution is considered appropriate when the absolute value of the score is less than 1.64. For this study, the Z-score was on the order of 0.9, which is well within the appropriate limits.

4. Results

The resulting outputs from this study are return frequency maps of maximum wind gusts. Contour plots were created for the 2-year, 5-year, 10-year, 25-year, 50-year and 100-year return

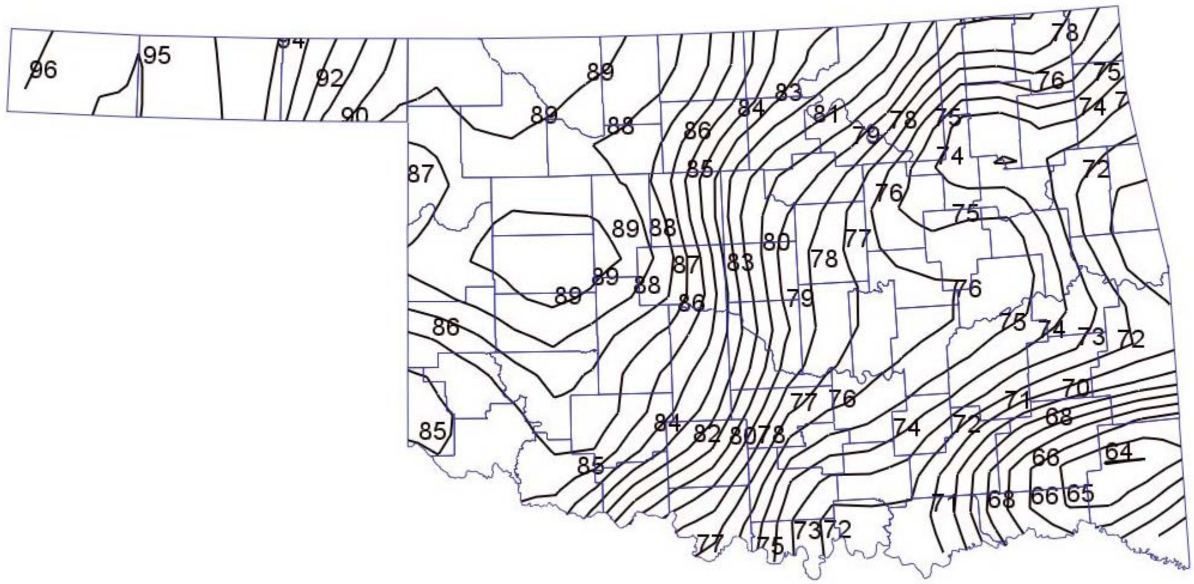

Figure 2. 10-year wind gust return map. Note the maximum in west-central Oklahoma.

periods for wind gust maxima. Each return period 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 wind gust measurements. Figure 2 is an example of the generated output. This figure 2 shows the 10-year wind gust maximum return, or what would be considered a 10-year wind event.

All stations with a length of record of at least eight years were plotted. All stations with shorter lengths were kept out of the contouring. The intervals of the contouring have been arbitrarily selected to give the most detail without cluttering the maps. The values of the contours are in miles per hour (mph) and are on the order of 1 mph for the 2, 5, 10, and 25-year return maps, while contours are every 2 mph on the 50 and 100-year return maps. Miles per hour were used in this study since these data will aid in putting severe wind events into perspective for the public.

The modeled output provides the characteristics of wind gust maxima across the state of Oklahoma. For all return periods, the wind gust patterns are consistent. The highest gust values are located in the northwest corner of the state, while the lowest values are located in the southeast. This pattern can be attributed to both geographical effects as well as meteorological. Geographically, higher elevations in the west coupled with barren vegetation would lend to higher wind speeds. Conversely, lower elevations and lush forests in the southeast part of the state would contribute to the lower wind speeds. Meteorologically, western Oklahoma is a common location for thunderstorms to initiate during the spring storm seasons. These thunderstorms produce strong wind gusts, and often will dissipate before they reach the eastern half of the state.

The contours reveal a localized maximum over west-central Oklahoma, as well as a localized minimum in southeast Oklahoma. Also, a tight wind gradient exists just west of central Oklahoma. This gradient runs north to south across the state, and it appears to mimic the shape of the dryline that occurs frequently during the spring convective season.

To further investigate this gradient, the spring wind gust data was pulled out from the year-round data set and was analyzed separately. If this gradient was due to spring convective storms and the dryline, the signal should be amplified by looking only at the spring wind gust data. Daily wind gust maxima from March through June were analyzed in the same manner as the full data set, and similar maps were produced for comparison. Figure 3 is an example of the spring return maps. Similar to figure 2, figure 3 is a 10-year return map.

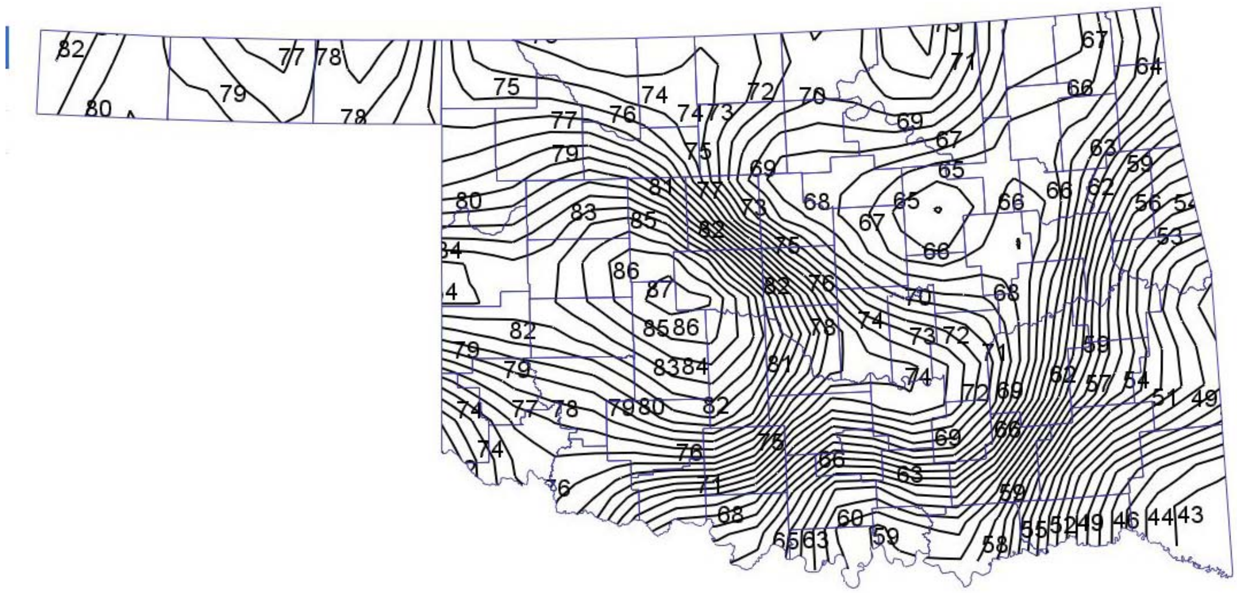

Figure 3. 10-year wind gust return map using data from March-June only.

The general characteristics of the spring maps are the same as the year-round maps. Stronger wind gusts are expected in the northwest part of the state, while the weaker winds are expected in the southeast. Some of the smaller details differ. The gradient in question in west-central Oklahoma is much stronger in the spring maps than in the year-round maps. The maximum values are consistent in the two sets of maps, but the eastern Oklahoma wind gust values are lower in the spring versus the year-round maps. This pattern would suggest that spring wind gusts in the western half of the state dictate the year-round modeled output, whereas in the eastern half of the state, wind gusts from a different time of year have more impact on the resulting maps.

5. Further Research

There are numerous ways to build upon, and improve this preliminary study. The data used in this research can easily be stratified and different elements can be brought to the forefront. Currently only year-round maps and spring season maps have been generated. This data can be broken down into seasonal or monthly subsets. One would expect to see different patterns to the wind gust returns based on time of year. Besides temporal stratification, the wind gusts can be analyzed by their direction or the time of day in which the maximum gust was recorded. Both analyses may produce potentially useful results.

6. Conclusion

The purpose of this study was to calculate the frequency return values of maximum wind gusts across Oklahoma using the Oklahoma Mesonet. The Oklahoma Mesonet provided 12 years of data for 108 stations across the state. Recurrence intervals of 2, 5, 10, 25, 50, and 100 years were calculated and contour maps of the data were produced. To further investigate, a subset of the data was extracted from the original data set, and a similar set of contour maps were produced.

The contour maps provided some interesting preliminary results. A gradient existed with maximum winds in the west and northwest parts of the state while the lowest winds were found in the southeast. A tight gradient can be found in west-central Oklahoma in the year-round maps, and this gradient is amplified in the spring season maps. Further stratification of the data set may yield more clues into the origin of this gradient.

The Oklahoma Mesonet proves to be a useful resource to the citizens of the state, as it effectively visualizes the wind gust patterns across the state. As the Mesonet data set continues to mature, it will become a more useful tool in computing accurate return rates of maximum wind gusts across the state.

7. Acknowledgements

This study was adapted from my M.S. study completed in 2005. I would like to thank Dr. Ken Crawford, Dr. Kevin Kloesel, and Dr. David Karoly for their guidance and insight on the topic.

8. 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 .

Hosking, J.R.M., and J. R. Wallis, 1997: *Regional frequency analysis – An approach based on L-moments*: Cambridge University Press, 224 p.

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.

Wilks, D.S., 1995: *Statistical Methods in the Atmospheric Sciences*: Academic Press, San Diego, CA, 467 p.