J3.20 UPDATING NOAA/NWS RAINFALL FREQUENCY ATLASES

Geoffrey M. Bonnin*, Bingzhang Lin, Tye Parzybok
Office of Hydrologic Development, National Weather Service, NOAA, Silver Spring, Maryland

1. INTRODUCTION

Civil Engineers use probabilistic estimates of rainfall intensities for particular durations and locations for the design of a wide range of structures from urban storm water drainage systems to dams and spillways. More recently their use has extended beyond the realm of civil engineering to include a broad array of environmental management and analysis concerns. In 1953 the National Weather Service began publishing rainfall-intensity-frequency-duration values or precipitation frequency estimates (Weather Bureau Technical Paper 24 1953). These values have become de-facto national standards by inclusion or reference in design and planning standards of a wide variety of agencies at federal, state, and local levels.

The current standards date from the 1960/70s. They are being updated based on a variety of improvements including: use of significantly longer data records, use of a regional L-moments analysis technique, an advanced spatial interpolation and mapping procedure, and web based delivery of the final product.

2. HISTORY AND CURRENT DOCUMENTS

As federal agencies began building large dams, they looked to an independent agency to make rainfall climatology estimates for use in design standards. The NWS filled that role by producing probable maximum precipitation estimates (estimates of worst case rainfall scenarios). While other agencies such as the U.S. Department of Agriculture had produced earlier precipitation frequency estimates, the National Weather Service role in worst case estimates was subsequently extended to probabilistic estimates over the full range of durations and expectations and sponsored by its fellow federal agencies.

The National Weather Service updated the initial publications in the early 1960's and most of the existing publications still date from that period.

3. CURRENT STUDIES

The Hydrometeorological Design Studies center located within the National Weather Service Office of Hydrologic Development is currently working on updates to the precipitation frequency estimates for the semiarid southwest (Todd et al. 2002) (Nevada, Utah, New Mexico, Arizona, Southeast California), the Ohio River basin and surrounding states (Raynault et al. 2002) (Tennessee, Kentucky, Illinois, Indiana, Ohio, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia, North and South Carolina), Puerto Rico and the Virgin Islands, and the Hawaiian Islands. The work of the Hydrometeorological Design Studies Center on both precipitation frequency and probable maximum precipitation is performed at the request of, and using funds provided by, a variety of federal, state, and local agencies.

Results of the current studies are expected to be published in 2003. They will provide rainfall estimates for durations of 5 minutes to 60 days and return periods of 2 to 1000 years. For the first time they will be accompanied by estimates of the uncertainty associated with the rainfall depth and intensity estimates. The studies improve on previous work by using a longer period of rainfall observations, state-of-the-art statistical methods and methods of spatial interpolation, and the results will be delivered via the Internet. Each of these is discussed in greater detail below.

Information on current documents and studies of the NWS Hydrometeorological Design Studies Center can be found on its web site at www.nws.noaa.gov/oh/hdsc.

	5 – 60 minutes	**1 – 24 hour**	**2 – 10 day**
Western U.S.	Frederick & Miller (1979) Arkell & Richards (1986)	NOAA Atlas 2 (1973)	Tech Paper 49 (1964)
Eastern U.S.	Tech Memo 35 (1977)	Tech Paper 40 (1961)	Tech Paper 49 (1964)
Hawaii	Tech Paper 43 (1962)	Tech Paper 43 (1962)	Tech Paper 43 (1962)
Alaska	Tech Paper 47 (1963)	Tech Paper 47 (1963)	Tech Paper 52 (1965)
Puerto Rico	Tech Paper 42 (1961)	Tech Paper 42 (1961)	Tech Paper 53 (1965)

Table 1. Current Precipitation frequency documents date from the early 1960's.

4. DATA

Weather Bureau Technical Paper 40 published in 1961 (Hershfield 1961) and still in use today for the eastern United States, used data through 1957. (The document is commonly referred to as TP40.) The average length of record for hourly data in TP40 was fourteen years. Additional data gathered since 1957 allows us to eliminate from consideration most stations with data lengths smaller than fifteen years in the semiarid southwest study. This clear improvement in the length of record available for analysis at individual recording stations increases the return period beyond

* *Corresponding author address*: W/OHD, 1325 East West Highway, Silver Spring, MD 20910
email: Geoffrey.Bonnin@noaa.gov

which the probability distributions need to be extrapolated. It also allows much greater confidence in determining the underlying probability distributions for the rainfall frequency estimates and thereby improves confidence in the extrapolation of the curves beyond the range of the observed data.

5. STATISTICAL APPROACH

Hosking and Wallis (1997), describe regional frequency analysis using the method of L-moments. This general statistical methodology stems from work in the early 1970's. It only began seeing full implementation for rainfall frequency estimation in the 1990's but is now accepted as the state of the practice. The National Weather Service is using Hosking and Wallis, 1997, as its primary reference for the statistical approach in its current studies.

The method of L-moments (or linear combinations of probability weighted moments), provides great utility in choosing the most appropriate probability distribution function to describe the rainfall frequency distribution. It also provides tools for estimating the shape (higher order moments) of the distribution and the uncertainty associated with the estimates.

The so-called "regional approach" recognizes that different observing stations can be assembled into groupings of similar climatic regimes (regions). It takes advantage of the similarity by assuming that stations within similar regions share the shape (not scale) of their rainfall frequency distribution curves. This assumption allows estimation of the shape parameters from the combination of the data from all sites in a climatic region rather than from each site individually, vastly increasing the sample data set used in the estimate. This produces much better estimates of the shape of the distribution and extends reliable extrapolations to more extreme events.

While the method derives the shape of underlying probability distribution function from groupings of observing sites, the mean of the distribution is estimated separately at each site. This feature is key to the approach the National Weather Service is using for spatially interpolating estimates (discussed below).

Regional frequency analysis using the method of L-moments includes tools for determining whether the data are likely to belong to similar climatic regimes as well as tools useful in examining the quality of the data record at individual observing sites. The method is particularly useful in that it accounts for the variation in period of record between individual observing sites, a common feature of the historical record.

6. SPATIAL INTERPOLATION

Rainfall frequency statistics are extracted for the specific locations of the rainfall gauges where the data was collected. This raises the question of how to interpolate between observing sites. Traditionally the estimates have been manually contoured taking subjective account of the terrain and climatology. NOAA Atlas 2 (Miller et al. 1973) augmented the subjective approach by using regression analysis based on climate and terrain factors as predictors.

Oregon State University's Spatial Climate Analysis Service has developed PRISM, a hybrid statistical-geographic approach to mapping climate data (Daly and Neilson 1992, Daly et al 1994, Daly et al. 1997). PRISM uses many of the predictive advantages of statistical techniques while integrating information concerning climate processes and variations and patterns from geographical studies. It produces fine scale gridded interpolations of climatic variables suitable for use in geographical information system (GIS) applications. PRISM is seeing growing acceptance as an effective tool for spatial interpolation of climatic variables and is being used by the National Weather Service to spatially interpolate rainfall frequency estimates.

For precipitation frequency estimates, there is a linear relationship between the mean of the underlying probability distribution function for particular durations and the estimated precipitation at particular frequencies. As noted earlier, the mean of the distribution at each location is estimated based solely on the data observed at that location whereas the higher order moments are estimated from homogeneous groups of observing sites. The National Weather Service has used this feature to achieve a cost effective approach to spatially interpolating the point estimates. PRISM is used to spatially interpolate only the means. The resulting fine scale grids of the distribution means are then converted to precipitation depth estimates at different frequencies using a multiplier computed as a function of the appropriate higher order moments. Adjustments are then made for potential spatial discontinuities between shape factors for different homogeneous regions. This approach allows us to make a single PRISM run for each duration rather than making estimates for each combination of duration and frequency.

One of the difficulties in interpolating precipitation frequency estimates is the lack of quality observations covering a broad variation in elevation, particularly observations at higher elevations. The current studies are able to make use of data collected by the Natural Resources Conservation Service's SNOTEL network, generally located at high elevation in the western U.S. There are locations where the quality of the observed data is insufficient for estimating the higher order statistical moments but is sufficient for estimating the mean of the distribution. We have used this knowledge by including the estimates of distribution means from all locations in the PRISM runs at the same time as being more selective in the stations that contribute to the regional estimates of the higher order moments of the probability distribution functions.

We have identified certain locations where the shape of the distribution function is not common with other stations. For these locations we include the distribution mean in the PRISM runs and then use the stations higher order moments when we operate on the resulting grids. We account for potential spatial discontinuities in these cases as well.

While the approach we use is referred to as a "regional" approach, the resulting estimates are unique at each observing site and at each point in the spatially interpolated grids. They are unique best estimates at each geographic location.

7. CLIMATE CHANGE

The current practice of precipitation (and river height and flow) frequency analysis makes the implicit assumption that past is prologue for the future. We extract rainfall frequency distribution characteristics from the historical record and apply the estimates in the design of future projects assuming the climate will remain the same as it was during the period of the analyzed historical record. If the climate changed in the past then the characteristics we extract are an “average” for the analyzed period, not specifically representing the period before the change or after the change. Furthermore, if the climate changes in the future, there is no guarantee that the characteristics we extract are suitable for representing the future lifecycle of the projects we are designing. Current climate change forecasts do not provide us with information that can be used to reliably define future changes in precipitation frequency distributions.

Lin and Julian (2001), examined data being used in the Ohio Basin study for potential climatic changes in the historical record. While they found changes, they were not of sufficient significance to discard any part of the record.

In its current studies the National Weather Service is assuming that the full period of the available historical record derived from rain gauges is suitable for use. However we will continue to examine the information being provided from improvements in climate change forecasting and we will continue to thoroughly examine the data we use in our analyses to determine if we should adopt a different approach.

8. PRODUCTS AND DELIVERY

The National Weather Service has developed the Precipitation Frequency Data Server (PFDS) for web-based delivery of precipitation frequency estimates (Parzybok and Yekta 2002). It will be used as the primary vehicle for delivery of precipitation frequency estimates and the associated documentation. We have prepared for delivery of three different types of document via the Internet; electronic documents, location specific estimates, and base grids. We have developed and tested the required software.

The documents themselves, including tables and maps, will available in Portable Document Format (PDF). They will be subdivided appropriately to avoid having to download massive data files to get specific information.

For more tailored information, the system allows a user with a standard web browser to download a variety of tables, charts and graphs (Figure 1) of precipitation frequency estimates. The estimates will be available for any user-selected point location in the United States and will also be available for user-selected areas up to 1000 km^2.

9. CONCLUSION

The current National Weather Service precipitation frequency estimates are used as de-facto national standards. They are in need of updating. Improvements in the data record and the science provide significantly better estimates on which to base design decisions. The Internet provides a more accessible mechanism for delivery of precipitation frequency estimates. The National Weather Service, with financial support from a variety of federal, state, and local agencies is working on updates for selected areas of the United States. It has demonstrated the technology, experience, systems, and partnerships to undertake and deliver a full national update. However funding must be identified before a national update can proceed.

ALL Season Precipitation Intensities (in/hr)

	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr	2-day	4-day	7-day	10-day
2-yr	3.47	2.57	2.10	1.44	0.88	0.55	0.37	0.22	0.14	0.09	0.05	0.03	0.02	0.02
5-yr	4.72	3.50	2.86	1.95	1.19	0.74	0.49	0.28	0.18	0.11	0.07	0.04	0.03	0.02
10-yr	5.76	4.28	3.49	2.38	1.45	0.90	0.60	0.33	0.21	0.14	0.08	0.05	0.03	0.02
25-yr	7.28	5.41	4.42	3.02	1.84	1.13	0.75	0.41	0.25	0.17	0.09	0.06	0.04	0.03
50-yr	8.60	6.39	5.22	3.56	2.17	1.34	0.89	0.48	0.29	0.19	0.11	0.06	0.04	0.03
100-yr	10.09	7.49	6.12	4.18	2.55	1.57	1.04	0.57	0.34	0.22	0.13	0.07	0.05	0.04

Text version of table

Unlike the values plotted in the graph below, the table values are rounded.

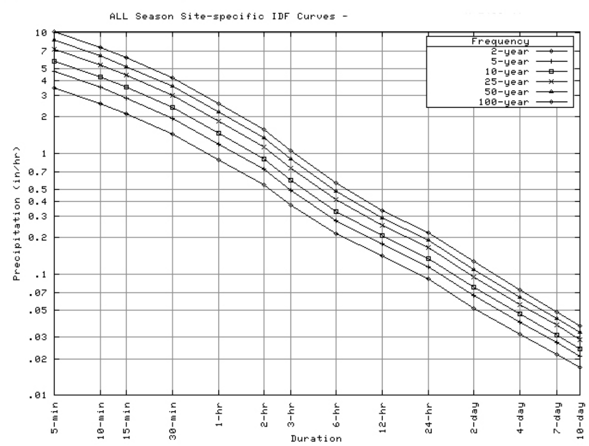

Figure 1. Data will be available at user-selected locations via the web.

10. REFERENCES

Arkell, R. E., and F. Richards, 1986: Short duration rainfall relations for the western United States. AMS Conference on Climate and Water Management – A Critical Era, Asheville, North Carolina

Daly, C., and R. P. Neilson, 1992: A digital topographic approach to modeling the distribution of precipitation in mountainous terrain. In: Jones, M. E., and A. Laenen, (eds.) Interdisciplinary Approaches in Hydrology and Hydrogeology. American Institute of Hydrology, pp. 437-454.

Daly, C., R. P. Neilson, and D. L. Phillips, 1994: A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology 33: 140-158.

Daly, C., G. H. Taylor, and W. P. Gibson, 1997: The PRISM approach to mapping precipitation and temperature. 10th AMS Conf. On Applied Climatology, American Meteorological Society, Reno, NV, Oct. 20-23

Frederick, R. H. and J. F. Miller, 1979: Short duration rainfall frequency relations for California. Third AMS Conference on Hydrometeorology, Bogota, Columbia

Hershfield, D. M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. Weather Bureau Technical Paper No. 40, U.S. Weather Bureau, Washington D.C.

Hosking, J. R. M., and J. R. Wallis, 1997: Regional frequency analysis, an approach based on L-moments. Cambridge University Press, Cambridge.

Lin, B., and L. T. Julian, 2001: Trend and shift statistics on annual maximum precipitation in the Ohio River Basin over the last century. Symposium on Precipitation Extremes: Predictions, Impacts, and Responses, 81st AMS Annual Meeting, Albuquerque, New Mexico

Miller, J. F., R. H. Frederick, and R. J. Tracey, 1973: Precipitation frequency atlas of the western United States. NOAA Atlas 2, 11 vols, National Weather Service, Silver Spring, Maryland.

Parzybok, T. and M. Yekta, 2002: NOAA/NWS precipitation frequency data server. Session on Internet Applications And Web Portals Part III, 19th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, Long Beach, California

Raynault, E., G. M. Bonnin, B. Lin, T. Parzybok, M. Yekta, D. Riley, and D. Todd, 2002: Updated precipitation frequencies for the Ohio River basin and surrounding states. Symposium on Observing and Understanding the Variability of Water in Weather and Climate, 83rd AMS Annual Meeting, Long Beach, California

Todd, T., G. M. Bonnin, B. Lin, T. Parzybok, M. Yekta, D. Riley, and E. Raynault, 2002: Updated precipitation frequencies for the semiarid southwest United States. Symposium on Observing and Understanding the Variability of Water in Weather and Climate, 83rd AMS Annual Meeting, Long Beach, California

U.S. Weather Bureau, 1953: Rainfall intensities for local drainage design in the United States. For durations of 5 to 240 minutes and 2-, 5-, and 10-year return periods. Part 1: West of the 115th meridian. Weather Bureau Technical Paper No. 24, U.S. Weather Bureau, Washington D.C.

U.S. Weather Bureau, 1961: Generalized estimates of probable maximum precipitation and rainfall-frequency data for Puerto Rico and Virgin Islands. Weather Bureau Technical Paper No. 42, U.S. Weather Bureau, Washington D.C.

U.S. Weather Bureau, 1962: Rainfall-frequency atlas of the Hawaiian Islands for areas to 200 square miles, durations to 24 hours, and return periods from 1 to 100 years. Weather Bureau Technical Paper No. 43, U.S. Weather Bureau, Washington D.C.

U.S. Weather Bureau, 1963: Probable maximum precipitation and rainfall-frequency data for Alaska for areas to 400 square miles, durations to 24 hours, and return periods from 1 to 100 Years. Weather Bureau Technical Paper No. 47, U.S. Weather Bureau, Washington D.C.

U.S. Weather Bureau, 1964: Two-to-ten-day precipitation for return periods of 2 to 100 years in the contiguous United States. Weather Bureau Technical Paper No. 49, U.S. Weather Bureau, Washington D.C.

U.S. Weather Bureau, 1965: Two-to-ten-day precipitation for return periods of 2 to 100 years in Alaska. Weather Bureau Technical Paper No. 52, U.S. Weather Bureau, Washington D.C.

U.S. Weather Bureau, 1965: Two-to-ten-day precipitation for return periods of 2 to 100 years in Puerto Rico and Virgin Islands. Weather Bureau Technical Paper No. 53, U.S. Weather Bureau, Washington D.C.

U.S. National Weather Service, 1977: Five to 60-minutes precipitation frequency for eastern and central United States. National Weather Service Technical Memorandum Hydro-35, U.S. National Weather Service, Silver Spring, Maryland.