Updating NOAA Rainfall Frequency Atlases

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Abstract

The rainfall frequency atlases and technical papers published by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) serve as de-facto national standards for rainfall depths at specified frequencies and durations in the United States. The current standards were published between 1961 and 1973. The NWS is currently updating the standards for the semiarid southwest, the Ohio River basin and surrounding states, Hawaii, Puerto Rico and the Virgin Islands, and is preparing to produce a comprehensive update of the standards for the rest of the country over a three-year period. The Hydrometeorological Design Studies Center located within the NWS Office of Hydrologic Development is responsible for the updates and its work is funded by other federal, state and local agencies. The update involves the use of significantly longer data records than were available in the 1960/70s as well as new and more effective statistical and mapping procedures. The primary keys to success are establishing a coalition of federal and state agencies to provide the resources and developing a consensus on technical approach.

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 elements through to dams and spillways. In 1953 the National Weather Service began publishing rainfall intensity-duration-frequency values (or precipitation frequency estimates) in 1953 (Technical Paper 24, U.S. Weather Bureau, 1953). These values have become de-facto national standards by inclusion or reference in design standards of a wide variety of agencies at federal, state, and local levels, from traditional civil works to environmental management in general.

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 National Weather Service filled

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Reprinted from Preprint Volume, 2002 Conference on Water Resources Planning and Management, May19-22, Roanoke, VA (Published by the Environmental and Water Resources Institute of the American Society of Civil Engineers).

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 NWS role in worst case estimates was subsequently extended to probabilistic estimates sponsored by its fellow federal agencies.

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

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

	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)

Current Studies

The National Weather Service is currently working on updates to its precipitation frequency estimates for the semiarid southwest (Nevada, Utah, New Mexico, Arizona, Southeast California), the Ohio River basin and surrounding states (Tennessee, Kentucky, Illinois, Indiana, Ohio, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia, North and South Carolina), Puerto Rico and the Virgin Islands, and Hawaii. These studies are expected to be completed 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 detailed estimates of the uncertainty associated with the rainfall depth estimates.

The current 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.

A National Study

The time is right for undertaking an update of the precipitation estimates for the country as a whole. The current documents are old and there is concern about whether climate change may have resulted in a shift in the values. We have an additional 40 years of data to add to the period of record used in older studies. There have been significant improvements in the methodologies used to make the estimates. Each of these improvements has been evaluated and incorporated into a working production system as part of the current studies. And the staff of the NWS Hydrometeorological Design Studies Center, who perform the work, have the experience and expertise gained through execution of the current studies. We have estimated that the update

could be achieved at a cost of approximately 3.5 million dollars spread over a three-year period. The National Weather Service is working to establish partnerships to provide sufficient funding.

Data

Weather Bureau Technical Paper 40 (TP40) published in 1961 (Hershfield, 1961) and still in use today for the eastern United States used data through 1957. The average length of record for hourly data in TP40 was 14 years. The additional data gathered since 1957 allows us to eliminate from consideration all hourly stations with data lengths smaller than 15 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 at which the probability distributions need to be extrapolated. The greater period of record also allows much greater confidence in determining the underlying probability distributions for the rainfall frequency curves and thereby improves confidence in the extrapolation of the curves for longer return period events.

Statistical Approach

Hosking and Wallis, 1997 describe regional frequency analysis using the method of L-moments. This approach, which stems from work in the early 1970s but which only began seeing full implementation in the 1990s, 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 method 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 of the distribution and the uncertainty associated with the estimates, as well as tools for determining whether the data are likely to belong to similar climatic regimes.

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 have in common 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 (reducing the sampling error). As a rough analogy, a region of 10 stations with 50 years of record can be analyzed as if it were a single station with 500 years of record; producing much better estimates of the shape of the distribution and extending reliable extrapolations to more extreme events.

Climate Change

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. 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 is suitable for use. However, we will continue to examine the information being provided from improvements in climate change forecasting and we will thoroughly examine the available data we use in our analyses to determine if we should adopt a different approach.

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, 1973) augmented the subjective approach by using regression analysis on climate and terrain factors.

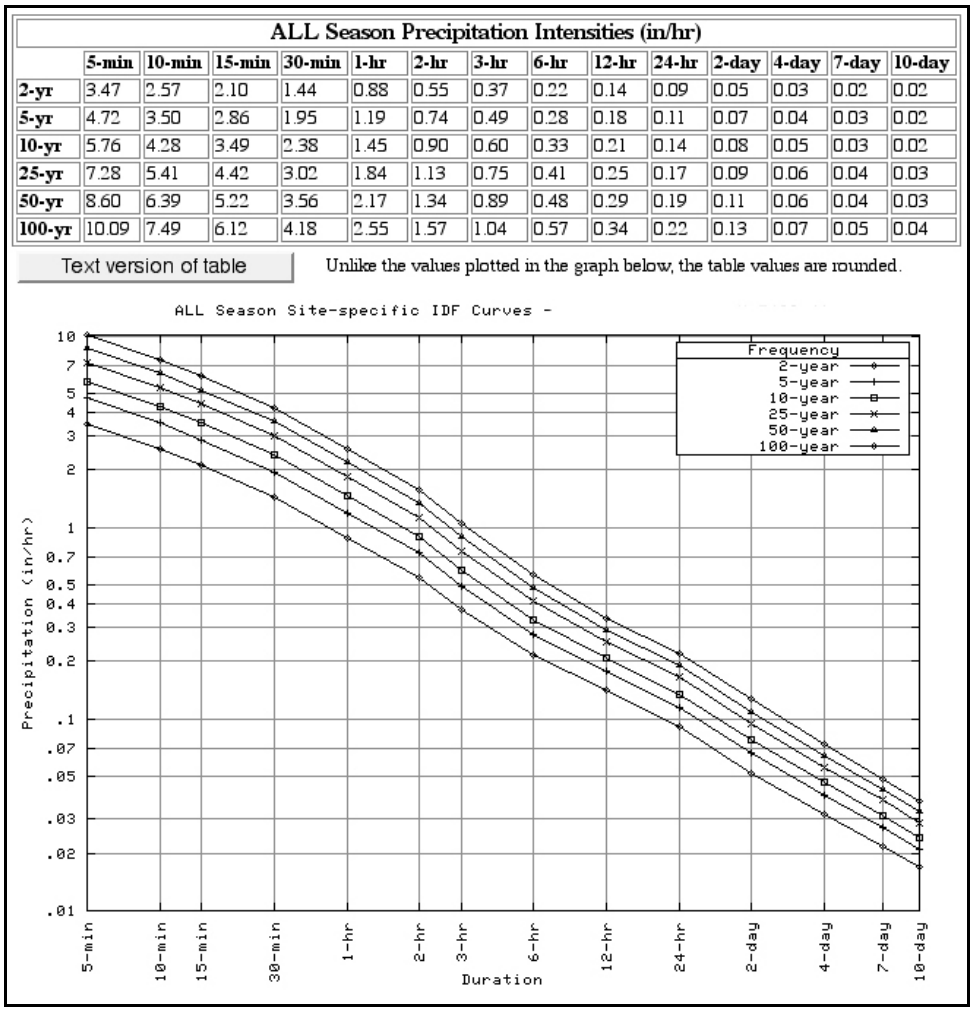
Oregon State University's Spatial Climate Analysis Service has developed PRISM, a hybrid statistical-geographic approach to mapping climate data (Daly and Neilson, 1992, Daly et al., 1994). PRISM retains many of the predictive advantages of statistical techniques while integrating information concerning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

Products and Delivery

Prior to delivery of final results, interim results will be distributed for review by interested parties external to the Hydrometeorological Design Studies Center as an independent quality check on the results. A limited run of paper copies of the final documents will be printed in anticipation of using the Internet as the primary vehicle for delivery. We have prepared for delivery of three different types of document via the Internet and have developed and tested the software needed to do it; electronic documents, location specific estimates, and base grids.

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

The National Weather Service has developed the Precipitation Frequency Data Server. The system allows a user with a standard web browser to download a variety of tables, charts and graphs (see 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.



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

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

The maps of precipitation frequency estimates will be prepared from grids of the estimates with a 30 arc-second grid resolution. These base grids will also be made available for download over the Internet. We understand a variety of developers plan to incorporate the base grids directly into their own software.

Conclusion

The current National Weather Service precipitation frequency estimates are used as de-facto national standards. They are in need of updating as a result of improvements in the data record and the science which will provide significantly better estimates on which to base design decisions. 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. It is hoped that a coalition that can provide financial support for a full national update can be assembled by the time this paper is delivered.

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

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