NOTES

Secular Trend in Extreme Rainfalls?

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ABSTRACT

Increasing attention has recently been given to many facets of climate change. This study focuses on a possible trend in extreme rainfalls in the past two decades based on the records of 135 National Weather Service stations in the eastern United States. The standard used to compare the recent data is Weather Bureau Technical Paper No. 40. The two frequencies examined are the 2- and 100-year 24 h return periods. No trend is discernible.

1. Introduction

Increasing popular and professional attention is currently being given to climatic change and its potential ramifications. In particular, some observers have perceived the frequency of large rainfalls to be much greater in the past two decades than historically. Because of the emphasis on climatic change, design engineers have of late become more sensitive to major storms that near some established critical standard and more alert to the possible need for corrective action to prevent a hydraulic structure failure. This sensitivity to the phenomenon of large storms is a symptom of an increased public awareness of the need for safety from natural events.

This note focuses on two aspects of rainfall frequency. The first is concerned with the methods and problems of preparing generalized probability estimates of extreme rainfalls and the second is concerned with using the estimates to determine the frequencies of the recent 20 years of extreme-value 24 h rainfalls. The results of this analysis will provide information on the comparative frequency and magnitude of rainfalls in the two periods, viz., prior to 1958 and 1958–77.

2. Preparation of rainfall frequency maps

Perhaps the most widely used source of the rainfall-duration-frequency data required in the hydrologic design of hydraulic structures has been U. S. Weather Bureau Technical Paper No. 40 (TP40), an atlas, published nearly 20 years ago which contains a series of rainfall frequency maps (Hershfield, 1961). TP40 was the product resulting from many rainfall frequency studies spread over the previous decade. More than 6000 24 h (once-daily measurements) stations were used to define the position of the 24 h isoluvials. The only other major source of rainfall frequency data was published 26 years earlier and reported records from only 200 stations (Yarnell, 1935). The long-term stations of TP40 (~60 years) provided the data for both the time and large-scale frequency characteristics and the short-term stations (~15 years) provided the detailed spatial characteristics.

There are 49 isoluvials in TP40, of which four are key maps. These four maps were used with duration and frequency relationships to obtain data for the other 45 maps. A comparison of the results of TP40 with those of Yarnell’s earlier study revealed only minor discrepancies at stations common to both studies even though the lengths of record differed by a factor of 2. However, in TP40 where additional on-site data were available, particularly in the mountainous regions of the West, the point differences approached a factor of 3.

A major problem in the construction of a series of closely related maps is to maintain internal consistency; i.e., the 10-year 1 h value cannot be larger than the 10-year 2 h value at the same point on their respective maps. The combination of smoothing and internal checks on a dense grid minimize the influence of outliers in the individual station series and, to a large extent, transcend the importance of the statistical distribution and the procedure for curve-fitting to just one duration.

3. Data and analysis

The purpose of this study is limited to comparing the 2-year 24 h and 100-year 24 h values as estimated from points on their respective maps in TP40 with independent data for the 20-year period, 1958–77.
TP40 maps were constructed from data available through 1957. Only the relatively flat eastern half of the United States is considered in the analysis because of the large rainfall differences in short distances in the mountainous regions of the western half. The addition of stations to the maps in the West would more than likely change the position of some of the original isopluvials in TP40 and shed no information on a trend in the most recent 20 years.

Series of annual maximum 24 h rainfalls were obtained for all National Weather Service stations that had complete records from 1958–77 and whose gage exposure, according to the station history, did not change significantly. The data from 135 stations were available for analysis; i.e., the largest rainfall in each year for a 1440 min period, not a calendar day or an observational day (EDS, 1958–77).

Two dichotomies were established with the independent data, with the 2-year 24 h and 100-year 24 h values, as estimated from their respective maps, serving as the separation points. The 2-year 24 h values in TP40 were reduced by 13% to convert from a partial duration series to an annual series in order to make them compatible with the test data. The partial-duration series contains all the values above a selected threshold where the number of items in the series is generally made equal to the length of record. The difference in magnitude of the 24 h values from both the annual and partial-duration series at the 2-year frequency is approximately 13% (Hershfield, 1961). No adjustment was necessary for the 100-year values. Fig. 1 displays the number of times that the 2-year values were equaled or exceeded during the 1958–77 period at each of the 135 stations. The expected value for each station is 10 (the 2-year value is the median of the series) but the observed frequencies vary from a low of 2 at St. Louis, Missouri, to 17 at Mt. Washington, New Hampshire. The average is 10.03 for the 135×20=2700 station-years of data. Since some of the annual maxima for nearby stations come from the same storm, the data are not completely independent in a statistical sense.

The number of times the 100-year 24 h value was equaled or exceeded is shown in Fig. 2. With 2700 station-years of record, the expected number is 27 and the observed number is 24. Three of the stations experienced two rainfalls of this magnitude during the 20-year period. However, only two pairs of stations experienced rainfalls greater than or equal to the 100-year value from the same storm; i.e., the annual maxima for Newark and Trenton, New Jersey, in 1971 were from the same storm. Rainfalls asso-
associated with Hurricane Agnes provided both Harrisburg and Williamsport, Pennsylvania, with their annual maxima for 1972.

4. Discussion and conclusion

Dettwiller and Changnon (1976) examined the seasonal maximum daily rainfall values at Paris, St. Louis and Chicago for 100 years of record in an attempt to discern a trend. They concluded that there was a significant upward trend in warm season heavy daily rainfalls at all three stations. Since Chicago and St. Louis are common to both studies, a comparison in data, methodology and results are worthwhile. Dettwiller and Changnon (hereafter denoted as DC) used seasonal calendar-day series, assumed normality of the time series, and regressed each series on a time scale with the regression coefficients (b values) serving as the criterion for significance. In this paper, a somewhat different set of data was used; namely the annual maxima for the 1440 min period containing the maximum rainfall. Unlike the DC series, the series here shows considerable skew. For St. Louis, the coefficient of skew is 2.03 and for Chicago it is 1.34; the coefficients of variation (standard deviation/mean) are 0.42 and 0.35, respectively. The latter two values, which are measures of variability in time, indicate the difficulty in identifying significantly dissimilar trends of extreme values in time.

With TP40 as the standard, Chicago experienced 14 annual maxima in the 1958–77 period greater than the 2-year value. This is in the same direction as the DC results. However, St. Louis experienced only two values greater than the 2-year value. One may speculate about the reasons for this relatively small number of occurrences. It could be the result of a change in gage location and exposure which occurred in 1955 at St. Louis, an artifact of the analysis employed, or the differences in the data; i.e., seasonal versus annual maxima and calendar-day versus 1440 min rainfall. In addition, seven of the annual maxima for St. Louis for the 1958–77 period did not occur in the warm season as defined by DC.

A limited sample from the most recent 20 years of data permits an interpretation of no significant change, on an aggregate basis, in the frequency and magnitude of extreme rainfalls. The perception by some of an increase in rainfall extremes over a broad area is more than likely due to an increase in the number of observing stations. Since rainfall is highly variable and discontinuous in space and of dimensions much smaller than most network grids, this is to be
expected. Another factor is the relative variability in time as measured by the coefficient of variation of a series of 24 h annual extremes. For the area of this study, the average is about 37%. This variability in time at a station is large enough so that it is not unusual for the range of the annual maxima at a station to exceed a factor of 4. This largely explains the uncertainty in the timing and frequency of extreme rainfalls.

REFERENCES