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TN 125 DISCUSSION

Point rainfall characteristics of Saudi Arabia

P. WAN

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The Author has carried out a valuable and potentially useful study of point rainfall characteristics of Saudi Arabia, particularly so in the context of the sparse hydrometeorological data usually encountered in this region. I basically agree with the principles behind the study but feel the clarification of the following comments would help to enhance confidence in the results.

29. The station–year concept, although a convenient method of overcoming relatively short periods of individual station records, needs to be handled with caution as implied by the Natural Economic Research Council.[4] In this study, although the homogeneity of the data may not be in question, one wonders if some of the stations are sufficiently far apart from each other to satisfy the assumption of independency. Also, it seems unlikely that the individual station records (of six years and less) will contain a selection of falls sufficiently varied to include the rarer events.

30. In carrying out the depth–duration analysis it is not clear why the Author assumed that data of the same rank in the series A, B, C and D have the same return period, even though the series are of unequal lengths. However, this may not affect the results as the depth–duration ratios were found to be independent of the return period.

31. It appears that a regression method has been adopted to fit the Gumbel distribution for the depth–frequency study. It is perhaps relevant that the moment fitting and maximum likelihood fitting methods have been shown to give better results.[5]

32. The expression used to compute the standard error of the estimates (equation (5)) presumably has it origin in Kaczmarek's study of the Gumbel fitting method for the double exponential (or Gumbel) distribution. However, Lowery and Nash[5] have shown this expression to be incorrect. They have derived the expression as approximately var $X(T)=(\sigma^2/n)[1+1{\cdot}14K+1{\cdot}10K^2]$ when the moments fitting method is used. The corresponding expression for the Gumbel fitting method, although similar, is different and in general gives higher variances (and standard errors).

33. Although Figs 2 and 3 are applicable to all the four rainfall zones considered it may be prudent to issue a word of caution on their application to zone A (and areas of similar rainfall characteristics) as Fig. 2 has been derived from results for zones B, C and D.

34. The study incorporated rain gauge stations from what would appear to be a relatively restricted region. The Kingdom of Saudi Arabia Ministry of Agriculture[6] claims that there is wide variability in the climatic and rainfall characteristics of Saudi Arabia. Also, the Red Sea convergence zone[7] is believed to cause higher rainfall in the coastal areas of the Red Sea. It therefore seems inadvisable to suggest the use of the derived results for the whole of Saudi Arabia.

35. The close agreement between the results of this study and those of Hershfield[1]

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and Bell[2] is interesting and supports their generalized relationships for short duration intense falls.

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The Author provides further confirmation of the remarkable consistency over a wide range of climatic conditions of the shape of depth–duration–frequency relationships derived from rainfall events of less than two hours in duration. In Fig. 2 he has used the ten year one hour rainfall depth as a reference value in preference to the two year one hour depth adopted by Hershfield *et al.*[8] and Reich.[9] The advantages of using the ten year one hour depth noted by Bell[2] were, first, that the fitting of frequency distributions introduces a smoothing which affects the ten year depth more than the two year depth and should therefore make the former more consistent with values estimated for longer recurrence intervals and, second, that the ten year depth is less likely to be associated with storm mechanisms other than convective activity. Nevertheless, the use of the two year one hour depth P_2^{60} as the reference value has the advantage from the practical viewpoint that it may be estimated from the mean annual maximum observer-day rainfall depth M and the mean annual number of thunderstorm days N. The relationship between these variables, which was originally derived from long rainfall records at many sites in the USA, is generally presented in graphical form,[8–10] but Bell[2] has shown that the following expressions may be applied for the same purpose with only a small loss in precision

$$\left.\begin{aligned} P_2^{60} &= 0{\cdot}17MN^{0{\cdot}33} \text{ for } 0 < M \leqslant 51 \text{ mm}, 1 < N \leqslant 80 \\ P_2^{60} &= 0{\cdot}617M^{0{\cdot}67}N^{0{\cdot}33} \text{ for } 51 < M \leqslant 114 \text{ mm}, 1 < N \leqslant 80 \end{aligned}\right\} \quad . \quad . \quad (6)$$

37. Provided that records of numbers of thunderstorm days are available (and such records are usually obtainable at least from stations located at air strips), P_2^{60} can be computed from equations (6) using only daily rainfall data. Once the estimate of P_2^{60} has been obtained, Bell[2] has shown that

$$P_T^t = (0{\cdot}35 \ln T + 0{\cdot}76)(0{\cdot}54t^{0{\cdot}25} - 0{\cdot}5)P_2^{60} \quad . \quad . \quad . \quad . \quad (7)$$

where t is the duration of rainfall, $5 \leqslant t \leqslant 120$ min., and T is the recurrence interval of the event, $2 \leqslant T \leqslant 100$ years. Equations (6) and (7) may therefore be used to synthesize the rainfall depth–duration–frequency relationships for sites without an autographic recorder. However, if rainfall data are available for durations shorter than the observer day, the records may be used to validate the synthesized relationships. I have recently applied this procedure in the construction of rainfall depth–duration–frequency relationships for sites in Portuguese Timor.[11]

38. The relationship between the ten year one hour rainfall depth and mean annual rainfall shown in Fig. 3 may be regarded as an alternative to equations (6). Could the Author give some indication of the scatter of the points about the line of relation in Fig. 3?

39. In discussing the criteria upon which the quality of the records from a particular rain gauge site was assessed, the Author states that '. . . most of them (the selected rain gauges) recorded efficiently more than 90% of the rainfall' (§ 3). Does this statement refer to a comparison between the total depths recorded at an autographic gauge and a nearby daily check gauge? Could the Author give a more detailed account of the quality control procedure?

Mr Wan

On the question of the validity of the station–year concept raised by **Mr Baghirathan**, a careful inspection of the hyetographs coupled with the fact that the nearest two stations were 6 km apart with the others at least 20 km from one another confirms the assumption of independence of data. There is seldom any discernible areal pattern associated with short duration falls because of the complex structure of storm cell clusters, although

some correlation exists between daily amounts and occurrences within relatively small areas. However, the main support of the validity of the assumptions made and the method used was provided indirectly by the good agreement of the derived depth–duration and depth–frequency ratios with worldwide values.

41. The intensity of the short duration storm is primarily a function of the storm mechanism associated with convective activity and is not necessarily related to annual rainfall depths or variability. The problem posed by the short period of individual station records was overcome by the use of the station–year method. As the generalized depth–duration–frequency curves in Fig. 2 are very similar to those from many other countries, it is quite valid to apply the relationship to the whole of Saudi Arabia until data on which to develop alternative relationships become available.

42. The difference between the ratios derived for station A and those for stations B, C and D resulted mainly from the fact that some intense rainfall at station A lasted less than the 60 min. rainfall used as the standard. Although statistical tests at 95% confidence level showed the ratios for A to be significantly different from those of the other stations, the values as shown in Tables 2 and 3 were so close that they could be considered to be similar for practical purposes. It is likely that with longer records these differences would be smoothed out.

43. In the derivation of the depth–duration ratios the same return period was assigned to data of the same rank in the series of rainfall depths for the duration considered for each of the four synthetic records treated separately. Hence, the fact that the series A, B, C and D are of unequal length is immaterial.

44. For the purpose of the analysis the method of moments was used and considered adequate. A more theoretically accurate method of fitting the data points might have produced marginally different frequency ratios without affecting the conclusions of the study. As regards the formula used to compute the standard error of estimates, the differences in the results using equation (5) and that advocated by Lowery and Nash[5] are very small.

45. In reply to **Dr Hall**, Fig. 3 was derived from Table 6 which indicates the precision of the ten year one hour rainfall for the 95% confidence level. However, it will be desirable in the future, when longer records become available, to produce a relationship with a narrower confidence band and to extend it to incorporate lower and higher rainfall zones.

46. As regards quality control, the total catch at recording stations was generally known accurately or estimated from adjacent gauges on the rare occasions when the inlet pipes were blocked or damaged. In the event of the recording mechanism failing to trace the rate of fall, the recorder would still act as a totalizer. The criterion used in the selection of the good quality stations was that the total catch accumulated over a year when the tracing mechanism was functioning properly was at least 90% of the total annual rainfall known accurately.

47. In Saudi Arabia thunderstorm day data are not available and would probably be unreliable unless recorded. Further, mean annual maximum daily rainfall is a much more variable quantity to be used for estimating a reference value. Equation (6) is therefore not applicable to Saudi Arabia in quite the way that it might be to a humid zone station.

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