Mausam, (1995), 46, 2, 175-180

551.577.22 (548.3)

1 to 10 days extreme rainfall studies for Kerala state

S. A. SASEENDRAN, K. K. SINGH, J. BAHADUR and O. N. DHAR*
National Centre for Medium Range Weather Forecasting
Department of Science & Technology, New Delhi
(Received 8 July 1993)

सार — केरल राज्य के 98 केन्द्रों में, दैनिक वर्षा के 80 वर्षों के आँकड़ों की मदद से, 1 से 10 दिनों तक की वर्षा की अवधियों के लिए, संभावित अधिकतम वर्षण (पी० एम० पी०) का आकलन किया गया है। वार्षिक आँकड़ों से पी० एम० पी० के आकलन हेतु हर्षफील्ड की सांख्यिकी तकनीक का उपयोग किया गया है। डिजाइन बाढ़ों के परिकलन के लिए अधिकतम वर्षण के आकलन में यह अध्ययन उपयोगी सिद्ध होगा। इसका उपयोग बांधों के जलनिकास तथा अन्य बड़े-बड़े जल-शक्ति निर्माणों के डिजाइन तैयार करने में किया जा सकता है।

ABSTRACT. The daily rainfall data for 80 years from 98 stations in Kerala region have been analysed to arrive at the Probable Maximum Precipitation (PMP) estimates for rainfall durations of 1 to 10 days. Hershfield's statistical technique has been adopted for the estimation of PMP from annual maximum data. The study will be useful in the estimation of extreme precipitation for computation of design floods, required for design of spillways of dams and other major hydraulic structures in the Kerala state.

Key words — Probable Maximum Precipitation (PMP), Rainfall, Enveloping curve, Duration, Extreme

1. Introduction

Probable Maximum Precipitation (PMP) may be defined as the maximum depth of precipitation that is physically possible over an area for a given duration. This concept is used in the estimation of extreme precipitation for computation of design floods utilised in the design of spillways and other major hydraulic structures. Methods based on physical and dynamic considerations (USWB 1960, 1961) have been developed by U.S. Weather Bureau for the estimation of PMP. Hershfield (1961, 1965) developed statistical empirical methods for PMP estimation from point rainfall data. The Hershfield technique has been widely accepted and used in many countries, such as, U.S.A. (Myres 1967), Canada (Bruce and Clarke 1966), Australia (Weisner 1970) etc. These studies have shown that Hershfield's method gives results comparative in magnitude with the conventional storm analysis method and can be used for estimation of PMP (Myres 1967). WMO (1969, 1970) has recommended this method for estimating extreme rainfall for small basins whose daily rainfall data at individual stations are available for a long period of time, but data for storm maximisation are not available.

For spillway design, the hydrological data available are, generally, found to be insufficient because for the reliable quantification of floods. Hundreds or thousands of years of streamflow records at the dam site under uniform climatic and stream channel conditions are required. It has become a general practice now to arrive at spillway design floods from an estimate of the PMP upstream. Recently, Indian Institute of Tropical Meteorology has published a Probable Maximum Precipitation (PMP) atlas for rainfall duration of one day using Hershfield's technique. Generalised maps of 1-day point PMP were also prepared by the India Meteorological Department (IMD) by adopting a combination of the physical method of moisture maximisation with Hershfiled's concepts which may lead to better estimates of PMP (IMD 1988). These studies are basically confined to rainfall duration of a day only. It has often been observed that rain spells occurring out of cyclones etc. usually have durations more than a day. Saseendran *et al.* (1983) have reported that mean of the highest observed rainfall for durations of 1 to 10 days over the state of Kerala varied from 29.9 to 104.3 cm. Keeping this in view, in the present study, an attempt has been made to derive PMP for durations of 1 to 10 days over the Kerala region, which would give an estimate of accumulated extreme rainfall over the State.

2. Data

Daily rainfall data for 80-year period (1901-80), from 98 reporting stations of India Meteorological Department (IMD) in Kerala state and closeby areas, have been used for the present analysis

* Indian Institute of Tropical Meteorology, Pune.

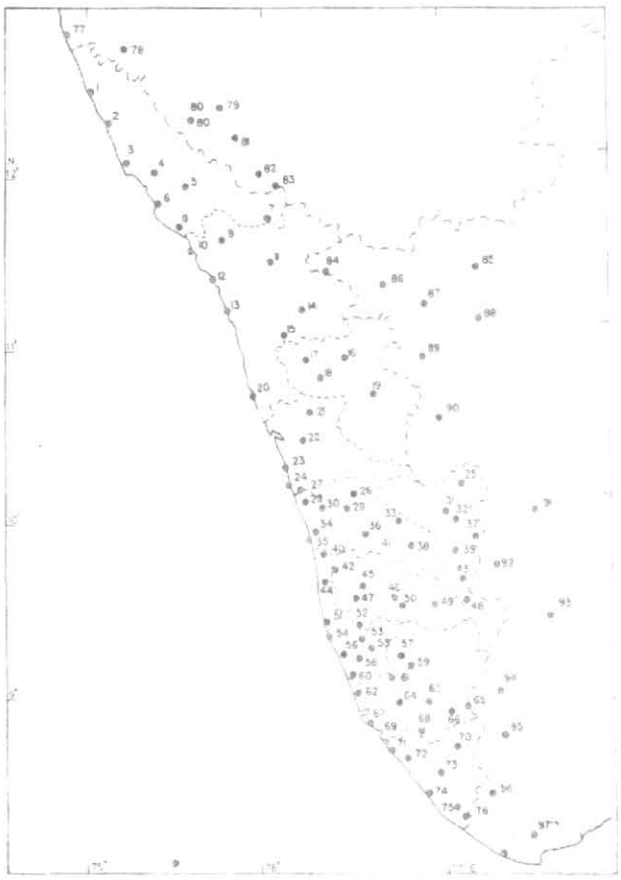


Fig. 1. Locator map of raingauge stations of Kerala

(Fig. 1). The analysis have been carried out after subjecting the data to a quality control program to minimise errors. The quality control measure comprises of comparing a particular data with the preceding and following values and also with the data from the neighbouring stations and eliminating the 'suspect' data with the help of a computer program evolved for the purpose.

3. Methodology

Hershfield's technique for the estimation of PMP is based on the general frequency formula of Chow (1951)

$$X_T = \bar{X} + \sigma K_T \qquad (1)$$

$\bar{X}$ is the mean of the annual maximum series, X_T the annual maximum value with a return period T years, σ the standard deviation of the series of annual maxima and K_T the frequency factor depending only on T and the assumed probability distribution. Value of K_T for the extreme value distribution type I (Gumbel) is given by Chow (1953) as :

$$K_T = -1.10 + 1.795 \log_{10} \log_{10} [T/(T-1)] \qquad (2)$$

Hershfield modified the general frequency equation as given below :

$$X_M = \bar{X} + \sigma K_M \qquad (3)$$

X_M is the PMP estimate for a station and K_M the frequency factor corresponding to the PMP estimate. The values of $\bar{X}$ and σ of the annual maximum series are worked out for a station, neglecting the highest value from the annual maximum series. The highest value is substituted for X_M in Eqn. (3) to get the value of K_M. Thus, specification of any return period or any statistical distribution to PMP has been avoided.

Hershfield calculated K_M values for about 2700 stations of the world and reached at a highest value of the order of 15 to be used in Eqn. (3).

Hershfield's technique has been widely used in India for estimating PMP for many meteorological sub-divisions of the Indian subcontinent (Dhar and Kamte 1969, 1971, 1973 and Dhar *et al.* 1971). It was concluded from their studies that except for Punjab and Haryana the value of K_M for other sub-divisions is much lower than Hershfield's value of 15. Wilson (1963) and Mazumdar and Rangarajan (1966) also have expressed their reservations in using a single value 15 for K_M for all meteorological sub-divisions of the world. As such in the present study, K_M values calculated for each of the stations are plotted against their $\bar{X}$ value for a single duration and an enveloping line is drawn Figs. 3 (a-e) and these enveloping curves are used for the PMP estimation as suggested by Hershfield (1961).

4. Analysis

The annual maximum values of rainfall for 1 to 10 days of consecutive duration were extracted from the daily rainfall records. The values of $\bar{X}$ and σ are calculated for each station separately. K_M values were also obtained for each station separately for the required durations using Eqn. (3). K_M values for each station are plotted against their $\bar{X}$ values and an envelope curve was drawn Figs. 3 (a-e). Envelope curves were prepared for all durations separately.

In short rainfall records (say 30 years), rainfall values of high magnitude (outlier) are often encountered which have high return periods of the order of 500 years (Hershfield 1961). Thus outlier increases the magnitude of mean and standard deviation of

TABLE 1

Salient features of PMP over the region (Vythiri)

Duration of rainfall (days)	Information on maximum observed rainfall over the region			Broad variation of PMP over the region	
	Rainfall recorded (mm)	Estimate of PMP for the same station (mm)	Ratio of PMP to miximum observed rainfall	Highest (mm)	Lowest (mm)
1	534	610	1.15	801	403
2	856	932	1.09	1002	602
3	1170	1293	1.10	1293	601
4	1434	1593	1.11	1592	704
5	1703	1932	1.13	1931	703
6	1943	2213	1.14	2214	802
7	2141	2481	1.16	2483	801
8	2222	2574	1.16	2572	1203
9	2300	2580	1.12	2581	1204
10	2430	2723	1.12	2720	1202

the series. The effect depends on the rarity of the outlier and the length of record. Also, the mean and standard deviation of the annual maximum series increase with length of record as the frequency distribution of the rainfall extremes is skewed towards right, resulting in larger magnitudes of PMP estimates with longer records than a short record. In order to compensate for these effects on the magnitude of the derived PMP, the coefficients of variation (CV) of the annual maximum series of each station were calculated and plotted. The CV of nearby stations were compared and wherever necessary, the values were adjusted by suitably changing their standard deviation. The revised values of standard deviations were then used for the calculation of PMP values of those stations whose CV values were adjusted. Eventhough, this procedure results in slightly lower values of PMP, they are expected to be more realistic.

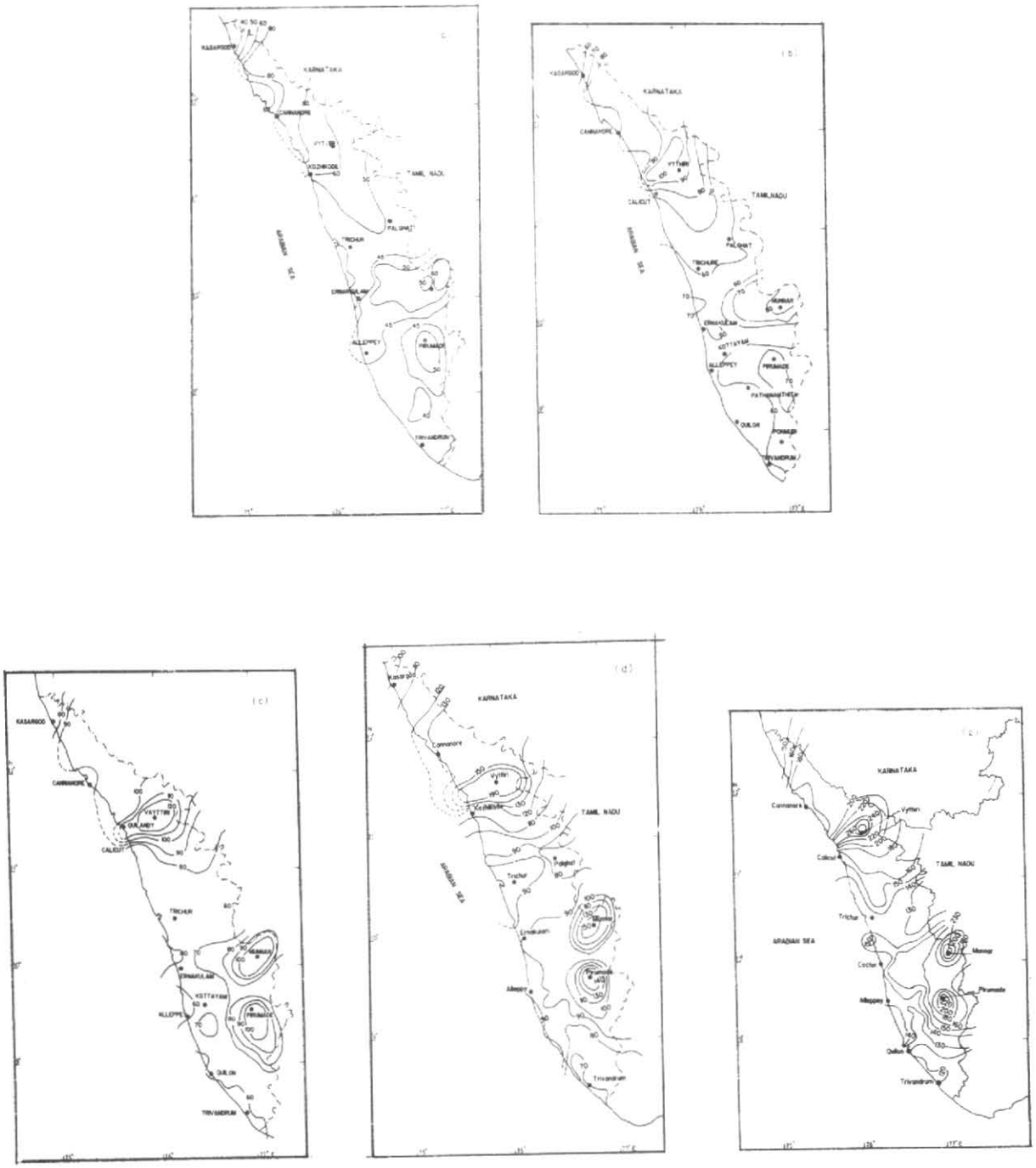
From the enveloping curve of K, the values of K for each station were extracted for their corresponding value of X and substituted in Eqn. (3) to get the estimate of PMP (X). The use of envelope value of K was found to increase the PMP values by an order of 5 to 30 per cent for durations of 1 to 10 days. This procedure was repeated for all the stations and for all the durations. The resulting PMP values were plotted on large scale base maps for the Kerala region and generalised charts were prepared separately for all durations considered in this study [Figs. 2 (a-e)].

5. Results and discussion

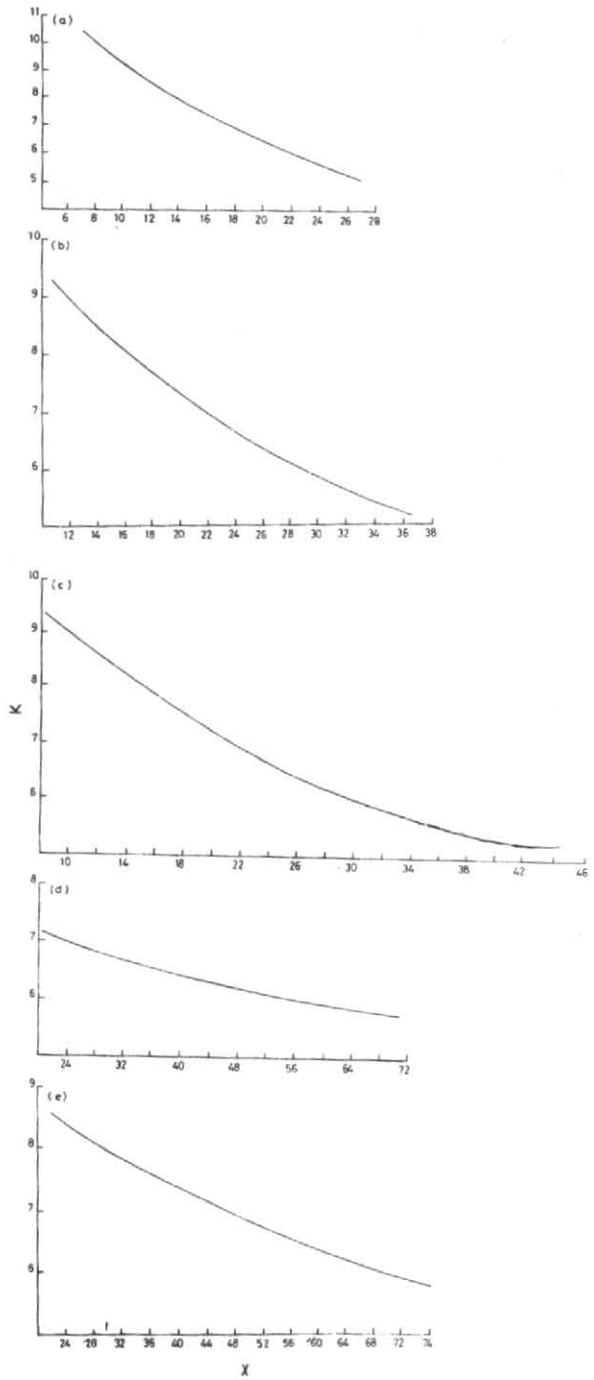
The generalised maps of PMP for the Kerala region for rainfall durations of 1 to 10 days are given in Figs. 2 (a-e). The isohyetals were found to follow, more or less, the contour pattern of the region. Highest values of PMP are found to be concentrated along and around the Western Ghats with comparatively low values towards the leeward side of the ghats as well as towards the coastal belt. This shows that the rainfall potential of the region increases from the coastal belt towards the Western Ghats reaching a maximum over the windward side of the ghats and rapidly decreases towards the leeward side. This brings out the orographic control over rainfall distribution over the region.

High amounts of PMP over the region are concentrated around the stations Vythiri, Munnar, Piramed and Cannanore falling in the districts of Wynad, Idukki, Kottayam and Cannanore respectively Figs. 2 (a-e).

The PMP estimate for the station located at Vythiri (1000 m above msl) which recorded the highest one-day rainfall (534 mm) over the state (Saseendran *et al.* 1983) was found to be of the order of 610 mm (for one-day duration). The salient



Figs. 2 (a-e). Generalised map of PMP (cm) for (a) 1-day, (b) 2-day, (c) 3-day, (d) 5-day and (e) 10-day for Kerala state



Figs. 3 (a-e). Envelope curves of K factor for (a) 1-day, (b) 2-day, (c) 3-day, (d) 5-day and (e) 10-day duration

features of the PMP estimates over the region for different durations are given in Table 1. The average ratio of PMP to the observed rainfall for different durations over the region was of the order of 1.13.

PMP values at individual stations for one-day duration as obtained in the present study were found to be comparable with those reported by IITM (1989) and IMD (1988). IMD values are slightly lower which is mainly due to the difference in the technique adopted by IMD. The studies reported earlier on the derivation of PMP are mostly for duration of one-day only, while the present study emphasises on durations of rainfall of more than a day, *viz.*, 1 to 10 days. This study is of paramount importance in the light of the fact that mostly floods and other rainfall-related water-logging problems in agriculture are caused by the accumulated effect of heavy falls for durations more than a day.

6. Conclusion

The daily rainfall data from about 98 stations for the period of about 80 years, over the Kerala region have been analysed to estimate PMP values for durations of 1 to 10 days. The study of extreme rainfall over the Kerala has brought to light that the average ratio of PMP to the observed highest rainfall value for different durations over the region is of the order of 1.13. The results will be useful to the design engineers in the derivation of design floods for the construction of various hydraulic structures in the region. The National Centre for Medium Range Weather Forecasting (NCMRWF) is envisaged to provide forecasts of rainfall in the medium range (3 to 10 days) for preparation of agro-advisories to the farmers. In this context this study can be utilised for warning the farmers on floods resulting from extreme rainfall events.

References

Bruce, J. P. and Clarke, R. H., 1966, Introduction to Hydrometeorology, Pergamon Press, New Delhi.

Chow, V. T., 1951, *Trans. Amer. Geophys. Un.*, **32**, 2, p. 231.

Chow, V. T., 1953, *Engg. Bull.*, Univ. of Illionis, No. 414.

Dhar, O. N. and Kamte, P. P., 1969, "A pilot study for the estimation of probable maximum precipitation using Hershfield technique", *Indian J. Met. Geophys.*, **20**, 1, pp. 31-34.

Dhar, O. N. and Kamte, P. P., 1971, "Estimation of extreme rainfall over North India", *Indian J. Met. Geophys.*, **22**, 3, pp. 559-566.

Dhar, O. N., Kamte, P. P. and Potnis, N. G., 1971, Proc. Symp. on Water Resources, Indian Institute of Science, Bangalore.

Dhar, O. N. and Kamte, P. P., 1973, "Probable maximum precipitation over Brahmaputra basin in Assam", *Irrigation-Power J.*, **30**, 3.

Hershfield, D. M., 1961, "Estimating probable maximum precipitation", *J. Hydraul. Div.*, Proc. Amer. Soc. Civ. Engr., **87**, Hy. 75.

Hershfield, D. M., 1965, *J. Amer. Wat.Works Assoc.*, **67**, 8.

Indian Institute of Tropical Meteorology (IITM), 1989, Probable maximum precipitation Atlas.

India Meteorological Department (IMD), 1988, Generalised maps of 1-day point probable maximum precipitation, Met. Monogr. Hydrol., No.11.

Mazumdar, K. C. and Rangarajan, R., 1966, "Regional Storm Analysis", *Indian J. Met. Geophy.*, **17**, Spl. No. 79-86.

Myres, V. A., 1967, Tech. Mem., W.B.T.M., Hydro-5, U.S. Weather Bureau.

Saseendran, S. A., Rakhecha, P. R., and Dhar, O. N., 1983, "Highest observed 1 to 10-day point and areal rainfall over Kerala State", *Indian J. Power & Rev.Vol. Div.*, 12.

U. S. Weather Bureau (USWB), 1960, Tech. Paper No. 38.

U. S. Weather Bureau (USWB), 1961, Hydromet. Report No. 36.

Weisner, C. J., 1970, "Hydrometeorology", Chapman and Hall Ltd., London.

Wilson, W. T., 1963, *Trans. Amer. Soc. Civ. Engrs.*, Discussions on Paper No. 3431, 128, 1, Pt. 1.

World Meteorological Organization (WMO), 1969, "Estimation of maximum floods", Tech. Note No. 98. WMO No. 233, TR. 26.

World Meteorological Organization (WMO), 1970, "Guide to Hydromet. Practices", WMO No. 168, TP-82.