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Spatial distribution of thunderstorm (short-duration) rainfall in lower Gangetic Basin*

P. S. HARIHARA AYYAR and K. MUKHERJEE

Meteorological Office, New Delhi

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ABSTRACT. An attempt has been made to determine the relationship between the rainfall recorded at a point and over the surrounding area in association with short duration thunderstorm rainfall over the lower Gangetic Basin. It is seen that in the case of short duration (6 hours or less) thunderstorm rain (*i*) the ratio of maximum average areal rainfall to maximum average point rainfall for an area of two thousand sq. km is about 75 per cent whereas for a larger area of ten thousand sq. km, it is of the order of 40 per cent; (*ii*) the percentage ratios of average areal rainfall to maximum point rainfall for areas of 2500, 5000 and 7500 sq. km are 40, 28 and 21 respectively; (*iii*) the distribution of point rainfall at different stations during thunderstorm activity can be represented in the form of an envelope curve, which will enable the probable maximum rainfall at any station to be computed knowing the maximum rainfall recorded and the distance of its occurrence; and (iv) simultaneous thunderstorm activity with rainfall in the lower Gangetic Basin appears mostly confined to an area of about 200 km radius.

1. Introduction

For the design and construction of railway bridges, road bridges and even culverts, it is necessary to have reliable estimates of the maximum likely discharge of water through the water channels below these structures. Among the essential items of information required in this connection is the probable maximum rainfall over different parts of the particular catchment area during different time intervals. The time intervals for which data are required vary from fractions of an hour to days depending upon the size of the catchment. A knowledge is also often required of the relation between the quantity of rainfall recorded at a point over the catchment and that over the surrounding areas at varying distances. In case an adequate network of self-recording raingauge stations is available, it is possible to prepare area depth curves or percentage area-depth curves for short period rainfall. Hershfield *et al.* (1957) have done this for the Ohio valley. Woolhiser and Schwalen (1959) have derived area-depth frequency curves for thunderstorm rainfall in South Arizona. A meso-scale study of rainfall over Poona and neighbourhood was made by the Institute of Tropical Meteorology, Poona in 1964.

In India, density of self-recording raingauge stations is not adequate for preparing area-depth curves for periods less than 24 hours. However an attempt has been made in the present paper to provide information regarding the relation between the maximum average rainfall over a selected area of the lower Gangetic Basin and the maximum average point rainfall recorded over the same area for short duration (thunderstorm) rainfall of three and six hours. The relation between the probable rainfall at a place in association with a thunderstorm in the area and the maximum rainfall associated with the thunderstorm has also been studied.

2. Analysis

(*a*) *Maximum average area rainfall and maximum average point rainfall* — The area chosen for study was the lower Gangetic Basin. Data are available for a period of 7 years (1961-1967) for ten self-recording raingauge stations in an area of about 10000 sq. km of this basin. Four of these are in an inner area of about 2000 sq. km. Thirtyeight typical situations in which thunderstorm activity was widespread during afternoon/evening were considered.

Hershfield *et al.* (1957) defined area to point rainfall ratio as follows —

$$\text{Rainfall ratio (area/point)} = \frac{\frac{1}{r}\sum_{i=1}^{r} A_i}{\frac{1}{nr}\sum_{i=1}^{r}\sum_{j=1}^{n} P_{ij}}$$

*The paper was presented at the Indian Science Congress held in Bombay in January 1969

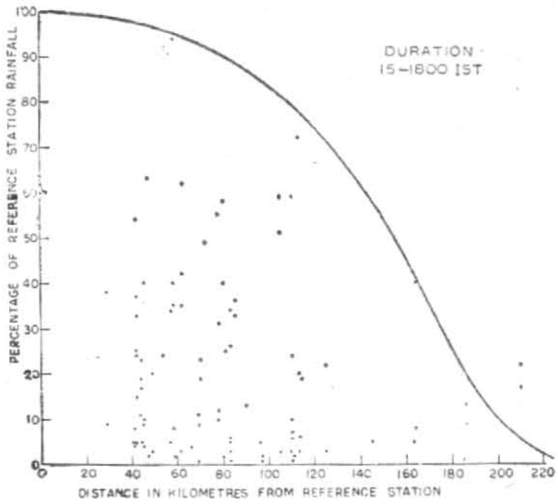

Fig. 1 (a)

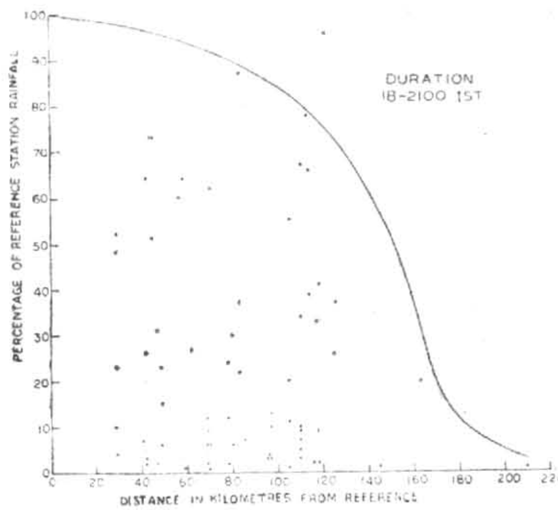

Fig. 1(b)

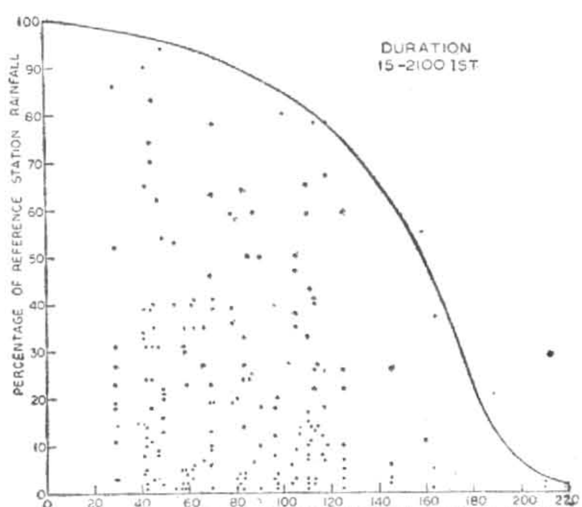

Fig. 2

Figs. 1 (a and b) and 2. Variation of rainfall percentages with distances from reference station for different durations

TABLE 1

Area (sq. km)	Duration (IST)	Ratio (Area/ point) Hershfield method (%)	Estimated by Hershfield and Wilson for USA (%)
2000	1500-1800	77	
	1800-2100	89	65 to 73
	1500-2100	70	
10000	1500-1800	40	
	1800-2100	36	46 to 65
	1500-2100	40	

TABLE 2

Relation between maximum point rainfall and average areal rainfall for 6-hour duration (1500-2100 IST)

Area (sq. km)	Regression equation
2500	$y = 0 \cdot 40\,x + 0 \cdot 22$
5000	$y = 0 \cdot 28\,x + 1 \cdot 98$
7500	$y = 0 \cdot 21\,x + 3 \cdot 35$

x = maximum point rainfall (mm)
y = average areal rainfall (mm)

where,

A_i = Maximum areal rainfall for i^{th} year,

P_{ij} = Maximum rainfall observed at j^{th} station in the i^{th} year,

r = Number of years of record, and

n = Number of stations in the network.

In the above expression, the numerator is the annual mean maximum areal rainfall for the particular duration and the denominator is the average of annual mean maximum point rainfall at different stations within the area. The results are given in Table 1.

It may be seen that for the network of stations available for the present study the ratios do not show appreciable variation with respect to time of the day or the total duration of rain.

Hershfield and Wilson (1960) have computed for tropical and non-tropical storms, the ratio of maximum average rainfall over various areas to that over 10 sq. miles for different durations. Assuming rainfall over 10 sq. miles to be practically point rainfall, it may be worthwhile to compare the results obtained in the present study with those of Hershfield and Wilson for six hour duration. These values are given in the last column in Table 1. It may be seen that there is fair agreement between the two estimates in the case of an area of two thousand sq. km whereas for a larger area of ten thousand sq. km the estimated percentage is somewhat less in the present study. The latter may be partly due to the number of self-recording raingauge stations, available for the present study over 10000 sq. km being not adequate.

(b) *Areal rainfall and maximum point rainfall* — In the preceding analysis, the annual maximum rainfall only was considered. As a further step, it was considered worthwhile to correlate the maximum point rainfall observed on each day considered for this study with the corresponding areal rainfall on that particular situation. The areas given are those over which rainfall has actually been recorded. The results are presented in Table 2.

(c) *Spatial variation of point rainfall* — Envelope curves were also prepared to obtain rainfall estimation for short duration at a station (or a very small area) when the maximum point rainfall recorded in association with a thunderstorm and the distance at which the maximum occurred are known. The above curves were drawn enveloping all the points obtained by plotting the rainfall of each station (expressed as percentage of the maximum rainfall observed at any station within the area considered) against the distance from the station having maximum rainfall. While drawing these envelope curves, a suggestion given by Court (1961) that an asymptotic approach to zero rainfall with increasing distance is desirable, has been kept in mind.

An estimation of the maximum rainfall at any station in relation to the rainfall at a station in the neighbourhood, where the maximum rainfall in association with the situation has occurred, can be made from the above envelope curves. It may be seen that beyond a distance of two hundred km the percentage ratio is very small in the case of short duration rainfall.

3. Conclusions

In the case of short duration (6 hours or less) thunderstorm rainfall, it has been observed that—

(*i*) The ratio of maximum average areal rainfall to maximum average point rainfall for an area of two thousand sq. km is about 75 per cent whereas for a larger area of ten thousand sq. km, it is of the order of 40 per cent;

(*ii*) The percentage ratios of average areal rainfall to maximum point rainfall for areas of 2500, 5000 and 7500 sq. km are 40, 28 and 21 respectively;

(*iii*) The distribution of point rainfall at different stations during thunderstorm activity can be presented in the form of an envelope curve, which will enable the probable maximum rainfall at any station to be computed knowing the maximum rainfall recorded and the distance of its occurrence and

(*iv*) Simultaneous thunderstorm activity with rainfall in the lower Gangetic Basin appears mostly confined to an area of about 200 km radius.

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