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USE OF 24 HOUR MAXIMUM POINT RAINFALL FOR DEMARCATING HOMOGENEOUS RAINFALL ZONES IN INDIA

P R Rakhecha,* A K Kulkarni,* B N Mandal,*& N R Deshpande*

ABSTRACT

The highest recorded 24-hour rainfall totals during the period 1875 to 1982 for about 300 stations were plotted and isohyets drawn to delineate the homogeneous zones of heavy rainfall. The isohyetal pattern indicated an unsteady increase from less than 20 cm in the far west and far north to over 50 cm on or near the coasts. There are a few inland stations where outstanding amounts have been recorded but these are randomly distributed in space and time. Besides, these, there existed a densly gauged area in the central peninsula lying between Latitudes 8°N to 21°N within which more than 20 cm of rain in 24 hours have never been recorded. The area which will be treated as meteorologically homogeneous with regard to the occurrence of heavy falls includes virtually the entire Indian region excepting the far western extremity, northern area bordered by the Himalayas and the central peninsular region. The correlation coefficient between the highest rainfall and elevation indicated no significant relationship.

INTRODUCTION

The rainfall in India is noted for its diversity both in space and time. The average annual rainfall varies from less than 20 cm in parts of West Rajasthan to over 1000 cm in the southern slopes of Khasi-Jainta hills. Another important feature is the occurrence of heavy falls of rain associated with certain meteorological situations all over the country independent of the annual averages of the different places. There are many places which have recorded about 40 per cent and some times over 100 per cent of their annual totals within a period of 24 hours (1). Such magnitudes of heavy rainfall over different parts of the country are important in many types of hydrologic studies concerned with efforts to determine runoff peaks and volumes.

The magnitudes of the highest rainfall are also useful as background material for workers investigating estimation of probable maximum precipitation (PMP) or extreme rainfall which is possible over a given point for a given duration. PMP is

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*Senior Scientific Officers,
Indian Institute of Tropical Meteorology Pune-5

that magnitude of rainfall which will yield flood flows where there is virtually no risk of being exceeded (7). Dhar et al (2) showed that at some places, the highest rainfall experienced are not far below their respective estimates of PMP : Such is an example of Bhagamandala station which recorded the highest 24-hour rainfall of 84 cm on 25 July,1924 and this was near its PMP estimate.

The map showing the distribution of 24-hour point maximum rainfall in India useful for hydrologic analysis was made by Iyer and Zafar(6) based on data of 30 years from 1891 to 1920. Later, Parthasarathy(8) updated this information based on data upto the year 1955. Dhar et al(3,4) while studying severe rainstorms of Gujarat and Rajasthan and Rao et al(9) for the rainstorm of Mahanadi catchment reported that many stations in these regions broke their previous 24-hour records.

In view of the high importance of the distribution of maximum rainfall in many types of hydrologic analysis, an attempt has been made in this paper to bring forward a generalized map of the highest point rainfall for 24-hour duration of the Indian region using latest data of about 300 stations uniformly distributed over different parts of the country and to delineate the homogeneous zones of heavy rainfall for storm transposition studies.

2. METEOROLOGICAL CAUSES OF HEAVY RAINFALL

Heavy to very heavy rainfall in different parts of the Indian regions occurs mainly in association with tropical storms (cyclonic storms/depressions) which form in the neighbouring seas of the Bay of Bengal and the Arabian sea and due to active monsoon conditions.

The tropical storms are intense low pressure systems in which the associated wind blows in counter clockwise and excceds 33 knots. When the associated wind speed is 34-47 knots, the system is referred to as moderate tropical storm, if the speed is 47-63 knots, it is severe tropical storm and when the associated wind strength is greater or equal to 64 knots the system is called as cyclone, Hurricane or Typhoon. The frequency of Tropical storms forming in the different months of the year over Bay of Bengal and Arabian seas taken together during the period 1891 to 1980 are given in Table 1. During the 90-year period about 900 tropical storms moved through the Indian region after crossing inland either from the Bay of Bengal or the Arabian sea. The average annual frequency of tropical disturbances in the monsoon season(June to September) and post monsoon season(October to November) are 7 and 3 respectively. These disturbances cause heavy falls of

rain along and near their tracks.

Table 1 Number of cyclonic disturbances which moved through the Indian region (1891-1980)

Month	a	b	Month	a	b
Jan	6	0.07	Jul	166	1.84
Feb	0	0.0	Aug	182	2.02
Mar	2	0.02	Sept	176	1.96
Apr	6	0.07	Oct	115	1.28
May	36	0.40	Nov	86	0.96
Jun	105	1.17	Dec	16	0.18

a - total number of tropical disturbances

b - average number per month

Normally, during the monsoon season the tropical disturbances (mainly depressions associated wind of 20-33 knots) form at the head of the Bay of Bengal to the north of 18°N and move in a westnorthwest direction across the country. Depending upon the tracks of these disturbances heavy rainfall occurs in the regions which are exposed to these moving storms. Sometimes when disturbances from the Arabian sea cross Gujarat coast and move in a northerly or northeasterly direction, north Gujarat and southern Rajasthan receive heavy falls of rain. Towards the end of the monsoon period, the depressions from the Bay of Bengal tend to recurve sometimes through Punjab and sometimes through Uttar Pradesh or further east and break up against the hills. They cause heavy rains both in plains and the hills of northern parts of India. Rainfall caused by depressions may vary from 20 to 30 cm in 24 hours.

During the postmonsoon season of October to December, cyclonic disturbances from the south Bay of Bengal strike coromondal coast and move inland and cause heavy to very heavy rainfall in the southern states of Tamil Nadu, Andhra Pradesh, Kerala and Karnataka. Some times these disturbances move in a northerly to northnortheasterly direction in the Bay of Bengal very close to the Tamil Nadu-Andhra coasts causing exceptionally heavy rainfall in the coastal areas of Tamil Nadu and Andhra Pradesh.

During the active monsoon conditions the trough line of the seasonal monsoon trough passes normally from Sri Ganga -

nagar to Balasore. Strengthening of the Arabian sea current of the monsoon results in heavy rainfall on the Western Ghats. When a depression forms off the Orissa coast often the Arabian sea monsoon currents get strengthened. This causes heavy rainfall in South Gujarat and over the upper reaches of the Godavari and Krishna rivers in Maharashtra.

3. HIGHEST RAINFALL RECORDED IN 24 HOURS

The highest recorded 24-hour (ending 8.30 a.m) rainfall totals during the years 1875 to 1982 inclusive, for about 300 first order stations uniformly distributed over the Indian region were extracted from various sources. The highest rainfall that has occurred during the period 1901 to 1982 for each of 300 stations has been extracted from the records held on magnetic tapes of National Data Centre, IMD, Pune and falls prior to 1901 were taken from various publications in which these data are summarised. The largest period available was 108 years and in many instances the length of record was less than this.

The highest 24-hour rainfall recorded at different stations based on the data for the years upto 1982 are plotted on a large scale map of India and isolines have been drawn at suitable intervals. The resulting isohyets are shown in Fig.1. It is of interest to see that the distribution of highest rainfall has been found reasonably smooth and exhibited fairly a definite pattern. This indicates that the incidence of heavy falls of rain have also certain preferences for certain regions. The main features of the map are as follows.

The isohyets of the highest 24-hour rainfall range between less than 20 cm over a large part of the interior peninsula, arid region of the west Rajasthan and northeast of Jammu and Kashmir to over 40 cm on and near coastal strips including Gujarat and Saurashtra coast, windward side of the Western Ghats, hills of Assam and foot hills of Himalayas. Rainfall exceeding 30 cm in 24 hours have also occurred over the central parts of India lying between Latitudes 19°N to 25°N and Longitudes 70°E to 84°E and over the northwest Indian region. Heavy falls exceeding 30 cm in 24 hours have also been occurred even in the arid and semiarid tracts of Rajasthan and Kutch where annual rainfall itself is 30 cm or less.

There are some places on or near the coasts like Bombay, Harnai, Vengurla, Cuddalore, Wandiwash, Kakinada, Paradip, Gopalpur and Contai and some places in the hills like Agumbe, Mount Abu, Khandala, Cherrapunji, Jowai and Mawsynram recorded heaviest falls to the extent of 60 to 100 cm in 24 hours indicating that phenomenal falls of greater magnitudes have

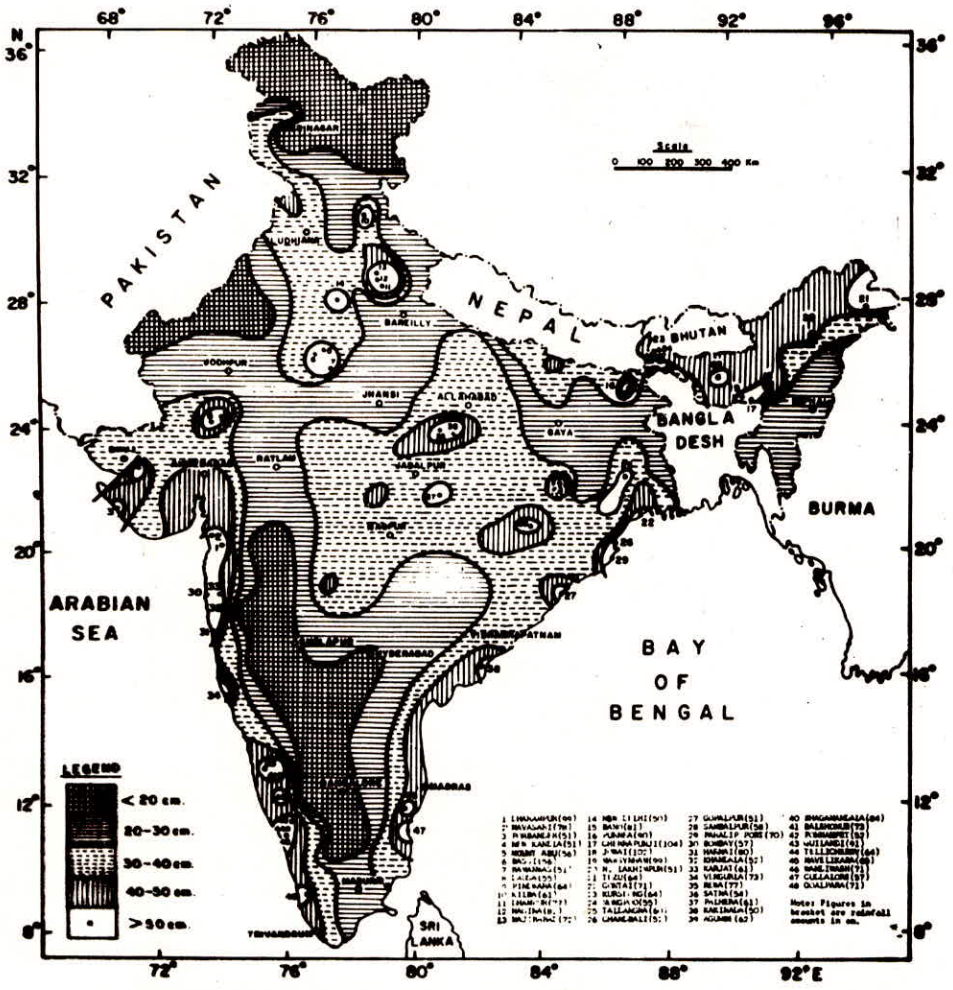

FIG. I. HIGHEST RAINFALL FOR 24 HOURS (PERIOD 1875-1982)

been restricted to the coastal and hilly areas. The highest 24-hour fall, 104 cm occurred at Cherrapunji in Khasi-Jainta hills. There are a few inland stations where outstanding amounts have been recorded but these are generally isolated occurrences. For example the highest in the Rewa-Satna area in Madhya Pradesh are between 60 to 70 cm whilst elsewhere the values are lower by 30 cm or so. Another example is 58 cm at Sambalpur supported by nearly 41 cm at Hirakud dam site. These falls were from Bay of Bengal depression which formed over northwest Bay on 17 August 1982. This storm has been discussed by Dhar et al (5). Also maximum rainfall exceeding 50 cm in 24 hours have also been recorded at Bamanwas, Bassi and Dausa stations located in semiarid region of Rajasthan. This storm has also been discussed by Dhar et al (4).

An analysis of the months of occurrence of highest rainfall over different parts of the country showed that the areas consisting of Gujarat, Rajasthan, Konkan, Madhya Pradesh, Uttar Pradesh and Orissa recorded the highest 24-hour rainfall during the months of July and August whereas the east coast of peninsula and Bengal recorded in the months of October and November. The tropical storms occuring in the post monsoon periods during the months of October to November affect the coastal belt in the east and cause heavy rainfall. However, most parts of Maharashtra and Bihar received such falls in the month of September.

4. UNPRECEDENTED RAINFALL IN 24 HOURS OVER DIFFERENT STATIONS

It has been seen in section 2 that cyclonic storms are major rain threat so far as heaviest rainfall is concerned. To help evaluating this threat the locations of intense rains associated with tropical disturbances were examined. A list of falls of 50 cm and above based on all available records is given in Table 2.

The outstanding inland falls during the recorded history of India both from the point of view of magnitude and the area covered were from the passage of cyclonic storms of Sept.,17-18, 1880 over northwest Uttar Pradesh and from July 2-4, 1941 rainstorm which brought extremely heavy rainfall and destructive floods in an area around Dharampur in Surat district of Gujarat. These rainstorms have been discussed by Dhar et al (1). The rainstorm of September,1880 was associated with the Bay of Bengal depression which crossed the Orissa coast on 14 September. During 16 to 17 September it moved northwestward and was centred near Neemuch. The depression thereafter recurved in a northeasterly direction and was centred near Agra on 18 September. During the passage of this depression many extremely high rainfall totals during 24 hours were

Table 2 Stations recorded rainfall of 50 cm or more in 24-hour (period 1875-1982)

Code No.	Station Name	State	Height (m)	24-hr Max. Rain-fall (cm)	Date
1	Dharampur	Gujarat	38	99	2. 7.1941
2	Navasari	"	25	78	2. 7.1941
3	Porbander	"	12	51	4. 9.1977
4	New Kandla	"	14	51	12. 8.1979
5	Mount Abu	Rajasthan	1195	56	1. 9.1973
6	Bassi	"	351	56	19. 7.1981
7	Bamanwas	"	-	51	19. 7.1981
8	Dausa	"	-	55	19. 7.1981
9	Pindwara	"	370	64	1. 9.1973
10	Kilba	Himachal Pradesh	-	61	27.12.1958
11	Dhampur	Uttar Pradesh	238	77	18. 9.1880
12	Nagina	"	250	82	18. 9.1880
13	Najibabad	"	240	72	18. 9.1880
14	New Delhi	-	216	50	9. 9.1875
15	Bano	Bihar	452	81	13. 9.1959
16	Purnea	"	38	90	13. 9.1879
17	Cherrapunji	Meghalaya	1313	104	14. 6.1876
18	Jowai	"	1390	102	11. 9.1877
19	Mawsynram	"	1401	99	10. 7.1952
20	N. Lakhimpur	Assam	102	51	22. 9.1956
21	Tezu	Arunachal Pradesh	197	64	30. 9.1972
22	Contai	West Bengal	11	71	3. 8.1977
23	Kurseong	"	1476	64	5.10.1968
24	Mongpoo	"	-	55	12. 6.1950
25	Taldaugra	"	-	60	10. 8.1950
26	Chandbali	Orissa	6	52	16. 9.1879
27	Gopalpur	"	17	51	24.10.1954
28	Sambalpur	"	148	58	9. 8.1982
29	Paradip port	"	4	70	10.11.1969
30	Bombay	Maharashtra	11	57	5. 7.1974
31	Harnai	"	20	80	5. 8.1968
32	Khandala	"	539	52	19. 7.1958
33	Karjat	"	107	61	18. 7.1958
34	Vengurla	"	9	73	25. 6.1958
35	Rewa	Madhya Pradesh	286	77	16. 6.1882
36	Satna	"	549	54	16. 6.1882
37	Palhera	"	-	57	30. 6.1961
38	Kakinada	Andhra Pradesh	8	50	2. 6.1941

Contd....

Table 2 Contd....

Code No.	Station Name	State	Height (m)	24-hr Max. Rain-fall (cm)	Date
39	Agumbe	Karnataka	659	62	27.7.1963
40	Bhagamandala	"	876	84	25.7.1924
41	Balehonur	"	907	73	6.7.1968
42	Ponnampet	"	857	52	16.7.1965
43	Quilandi	Kerala	8	91	28.5.1961
44	Tellicherry	"	-	64	25.5.1969
45	Mavelikara	"	-	65	24.7.1967
46	Wandiwash	Tamil Nadu	-	71	5.8.1965
47	Cuddalore	"	12	57	18.5.1943
48	Goalpara	Assam	-	71	8.6.1970

Note : Code No. of these stations are shown in Fig.1

registered in the northwestern plains of Uttar Pradesh. In this region 3 stations namely, Nagina, Dhampur and Najibabad which are listed in Table 2 recorded rainfall of the order of 82 cm, 77 cm and 72 cm respectively on 18 September,1880 and these records of 24-hour duration have not yet been exceeded.

The rainstorm of July,1941 was caused by the depression which formed in the head Bay of Bengal on 28 June. It moved to Orissa coast on 30 June. After crossing the coast it moved westnorthwestwards and got filled up over south Rajasthan on 4 July. In association with the movement of this depression the monsoon current from the Arabian sea got strengthened and rainfall over the coastal plains of south Gujarat-north Konkan was heavy to very heavy on the morning of 2 July. Dharampur, a station in south Gujarat recorded about 99 cm of rainfall in 24 hours ending 0830 hrs on 2 July. This is a record rainfall for a plain area station in India for 24-hour duration and has not uptil today been surpassed. It is thus seen that the cyclonic storms are major threat in so far as heaviest rainfall is concerned.

For flat areas the Indian record 24-hour rainfall total which resulted from a tropical storm is 99 cm at Dharampur while for mountaineous area it is 104 cm at Cherrapunji on the southern side of Khasi-Jainţa hills. It can be presumed that the rainfall potential for mountaineous areas is more or less equal to that for flat areas for duration of about 24 hours. However, for flat areas the world record 24-hour rainfall total which resulted from a tropical cyclone is 107.2 cm

at Kadena, Okinawa, while for mountaineous area it is 182.5 cm at a very steep volcano on the island of La Reunion in the Indian ocean.

5. RELATION BETWEEN HIGHEST RAINFALL AND ELEVATION

The relationship between maximum 24-hour rainfall and elevation has been investigated both graphically as well as statistically with a correlation analysis. Maximum 24-hour station rainfall given in Table 2 were plotted against station elevation. The scatter plot of the maximum rainfall versus elevation showed no consistent relationship between the two parameters. The relationship between these two parameters was further investigated statistically with a correlation analysis. The numerical value of correlation coefficient was found less than 0.4 which was not significant.

6. METEOROLOGICAL HOMOGENEOUS ZONES FOR STORM TRANSPOSITION

For the estimation of probable maximum precipitation(PMP) over a catchment when the sample of severe rainstorms within the catchment is not adequate, the record of storm is increased by transposition of major storms from meteorologically homogeneous zones. Zones of meteorological homogeneity are defined as areas in which the probability of occurrence of a storm of a given intensity is the same throughout an area. Strictly speaking, the heavy rainfall is therefore, same at all points in such an area. The distribution of heavy rainfall (Fig.1) has been found reasonably smooth and exhibited fairly a definite pattern indicating that the incidence of heavy rainfall have certain preferences. The isohyetal pattern of highest rainfall indicated an unsteady increase from less than 20 cm in the far west to over 50 cm on or near the coasts. There are a few inland stations where outstanding amounts have been recorded associated with monsoonal depressions, but these are randomly distributed in space and time. It has however, been seen that there existed a densly gauged area in the central peninsula lying between latitudes 8°N to 21°N within which more than 20 cm of rain in 24 hours have never been recorded. The area which will be treated as meteorologically homogeneous includes virtually the entire subcontinent excepting the far western extrimity, northern area bordered by the Himalayas and the central peninsular region.

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