Correspondence

Comments on 'Rainfall estimates of one-day PMP for India' by P R Rakhecha and C Clark (Meteorological Applications, 1999, 6: 343–350)

The authors of the paper 'Rainfall estimates of one-day PMP for India' have used in their study the Depth-Area-Duration (DAD) data of eleven severe rainstorms for standard areas, from point to 20,000 km². This data has been given in Tables 1 and 2 of the paper for one-day duration. In this connection it is pointed out that of the eleven severe rainstorms, only for one of the rainstorm, was Rakhecha the principal investigator while for other ten rainstorms principal investigators were different scientists from the Indian Institute of Tropical Meteorology (IITM), in Pune, India Meteorological Department (IMD) and Central Water Commission, New Delhi. Complete list of these eleven rainstorms is given in Table 1 together with the names of scientists who have carried out detailed analysis of these severe rainstorms and got them published in various scientific journals.

In fairness to the scientists concerned, Rakhecha and Clerk should have referred to all those eleven rainstorms in a proper scientific manner as is done in standard scientific journals. At present an erroneous impression is created among the readers that all the eleven rainstorms were analyzed by Rakhecha and Clerk, the authors of the above paper.

Secondly, the technique which the authors have used in obtaining one-day Probable Maximum Precipitation (PMP) for the Indian area is not at all clear. The maps drawn by them showing isopleths of PMP have no latitude and longitudes shown on them. It is, therefore,

Table 1. *List of authors who analyzed the eleven rainstorms which have been referred in 'Revised estimates of one-day PMP for India' by P. R. Rakhecha and C. Clark*

Rainstorm year	Reference
1880	O. N. Dhar, O. N., Rakhecha, P. R. & Mandal, B. N. (1975). A hydromet study of Sept. 1880 rainstorm which caused the greatest raindepths over northwest Uttar Pradesh. *Irrig. Power J.*, **32:** 1, 81–86**.**
1926	Raman. P. K. & Dhar, O. N. (1968). A study of major rainstorms of Bihar and Madhya Pradesh for evaluation of design storms. *Indian J. Meteorol. Geophys.*, **17(Special issue):** 87–96.
1927	Dhar, O. N., Rakhecha, P. R. & Mandal. B. N. (1981**).** Severemost rainstorm of July 1927 which caused devastating floods in Gujarat region. In *Proc. International Conference on Flood Disasters,* Indian National Science Academy, New Delhi, 200–210.
1930	Dhar, O. N., Mulye, S. S. & Nandargi, S. S. (1987). Was the lower Godavari basins rainstorm of August 1986 unprecedented. *Acquaworld*, **II;** 384–390.
1941	Dhar, O. N., Kulkarni, A. K. & Mandal, B. N. (1984). The most severe rainstorm in India a brief appraisal. *J. Hydrol. Sci.*, **29:** 2, 219–229.
1943	Rakhecha, P. R., Kulkarni, A. K., Mandal, B. N. & Sangam, R. B. (1992). A hydrometeorological study of May, 1943 rainstorm over Tamil Nadu a historical event in the pre-monsoon season. *Journal of Indian Association of Hydrology (IAH)*, **15:** 65–73
1955	Dhar, O. N. & Rakhecha, P. R. (1976). A study of October 1955 rainstorm which caused unprecedented rainfall in Beas Sutlej region. In *Proc. of Conference on Hydrology of Flood Control with Special Reference to the Beas and Sutlej Rivers*, Nangal, 1–13.
1965	Dhar, O. N., Mandal, B. N. & Mulye, S. S. (1987). A brief appraisal of severe rainstorms of Madhya Pradesh region for optimum development of its water resources. *Indian J. of Power and River Valley Development*, **37:** 88–93.
1968	IMD (1968). *North Bengal Storm*. Hydrology Directorate, Indian Meteorological Department (IMD), New Delhi. (Not published).
1981	Dhar, O. N., Rakhecha, P. R., Mandal, B. N. & Sangam, R. B. (1982). Was the July 1981 rainstorm over Rajasthan is unprecedented?. *J. Pure Applied Geophys*. (PAGEOPH), **120:** 483–494.
1982	Kathuria, S. N., Saxena, R., Kulkarni, S. D. & Mohile, A. D. (1993). A hydrometeorological aspects of August, 1982 rainstorm over Orissa. *Publication No. 234*, Central Board of Irrigation and Power, New Delhi, 21–28.
Storms up to 1982	IITM (1994). *Atlas of Severe Rainstorms of India*. Indian Institute of Tropical Meteorology (IITM), Pune, 1–60.

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difficult to compare point PMP values of their maps with the PMP Atlas of IITM.

One-day PMP Atlas prepared by IITM Hydromet Scientists (including the senior author of the above paper) has been acclaimed in the country as the one giving correct estimates of one-day PMP based on modified Hershfield technique, taking into consideration physiographic features of the country. In the present paper by Rakhecha and Clark it is seen that PMP estimates obtained by them are 75 to 250% higher than those obtained in IITM PMP Atlas. As an example, station like Leh (Jammu & Kashmir) whose mean annual rainfall is hardly 10 cm, its one-day PMP has been worked out as 60 to 80 cm which is too much high. Delhi PMP for one-day is of the order of 69 cm but the value given in the paper is of the order 120 to 130 cm, that is more than the double of the annual value.

The general feeling here is that PMP values obtained by Rakhecha and Clark using Hershfield technique have been further moisture maximized which has resulted in giving very high values for one-day PMP. It is requested that authors should explain in simple language without technical jargon what has prompted them to maximize the already maximized Hershfield estimates and what is the sound theory behind it. In extreme regions of this country, PMP estimates have been worked out of the order of 60 to 80 cm per day while the mean annual precipitation values of these regions varies from 10 to 65 cm. There are a good number of such fallacies in their PMP maps (Figures 4 and 5). If these PMP values are taken into consideration for design storm estimation, the project coasts will escalate very much causing serious concern among planners and design engineers on the one hand and hydrometeorologists on the other of this country.

Considering the very exaggerated estimates given by Rakhecha and Clark, naturally the hydrometeorologists of this country are greatly disturbed and therefore would like to have a clarification from Rakhecha and Clark on this whole matter.

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Reply to the comments on 'Rainfall estimates of one-day PMP for India'

We thank Drs Dhar and Nandargi for their interest in our two papers. Our sources of data were quoted in the first paper, namely Publication No 234 of the Central Board of Irrigation and Power (CBIP, 1993). In that publication we took data from several papers including two co-authored by Dr Dhar and Nandargi. Point and areal rainfall for the 1941 storm were given by Dr Ramasastry, Dr Upadhyay, and Dr Dhar *et al*. The other source of data was the paper by Rakhecha & Pisharty (1996). The storm data listed by Dhar and Nandargi are old as compared with the new data published in CBIP (1993).

We note the list of papers given by Dhar and Nandargi. However, this list is not complete. The storms of 1926, 1941, 1955, 1981, and 1982 were analysed by people before the relevant papers in their list were published:

- 1926 storm: Raman & Chinabra (1966);
- 1941 storm: Parthasarthy *et al*. (1960);
- 1955 storm: Parthasarthy (1959);
- 1981 storm: Sharma (1981);
- 1982 storm: Rao et al. (1986).

We are sorry that Drs Dhar and Nandargi found our methodology hard to understand. We used the WMO manual (WMO, 1986) for estimating Probable Maximum Precipitation (PMP). The PMP estimates at different locations were determined by maximising the highest rainfalls. Where possible, transposition was applied to achieve the PMP. Before doing this, an attempt was also made to determine the likely rainfall for 10 km^2. This was done for the reason that the highest rainfall might have been missed due to the low density of raingauges in India. In this connection it is very pertinent to mention that if England had kept the density of raingauges as existed in India 100 years ago, it is possible that the highest recorded daily catch would be only around 100 mm. However, the higher raingauge network has led to much higher falls (Bleasdale, 1960), such as 280 mm in Dorset in 1955, and 243 mm at Bruton in 1917.

We did not use the Hershfield method for two reasons. First, Rodda (1970) experimented on a rare storm in England with this method and concluded that the method gave meaningless results. Second, on page 282 of WMO No. 282 (WMO, 1986) it is stated that statistical methods like Hershfield's method 'are generally not considered as reliable as those obtained by use of procedures based on a comprehensive meteorological analysis. Every effort should be made to complete additional studies to support the results obtained by statistical procedures.' We also note that the Probable Maximum Precipitation Atlas (IITM, 1989) was published over two years after the publication of WMO No. 282. The results of the IITM Atlas show frequent variations in the estimates of PMP often centred around single stations, for example in Gujarat State. In the IITM Atlas it would also have helped to assign a return period to the PMP values. Normally a value of 1 in 1 million ($P = 0.000001$) would be taken where there is a risk of loss of life as a result of a dam failure incident. Such an approach is not over cautious because there are so many uncertainties in trying to estimate rare events, and in any case there have been several serious dam failure incidents in India.

It is from the evidence of historic floods that has given us the greatest concern about the IITM PMP values.

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We give some examples to back them up.

- At the Damanganga Dam with a catchment area (CA) of 1813 km² a flood took place in 1976 (Mistry, 1993), with a peak discharge of 26884 cumecs. By reversing the Rational equation, assuming a runoff percentage of 80% for 8–10 hours response time gives a point value for the rainfall of 630–790 mm in one day. For this area the IITM Atlas gives a PMP value of 700 mm.
- The Mitti dam site has a CA of 468 km² and it too had a flood in 1988 with a peak flow of 5012 cumecs. Using the IITM Atlas, 80% runoff, and a 7 hour storm profile gives a peak discharge of 4460 cumecs. Obviously the recorded flood could not be taken as the Probable Maximum Flood (PMF). Similar results are obtained for the Kaddam Dam and the Moj Dam site.

The uncertainty of the PMP values from the IITM Atlas are further demonstrated from the study of Kumar *et al*. (1999). They looked at the regional flood frequency for central India, including Gujarat State. In their regions called 3a and 3e, they predicted floods with return periods up to 1000 years. To obtain the 1000 year flood in zone 3a, a design rainfall of 600–1000 mm is needed. The PMP value from the IITM Atlas for this area is about 800–1000 mm. For zone 3e (south central) the design rainfall could be 420 mm as compared with 400 mm. Thus the PMP value for the IITM Atlas gives the 1000 year flood event. It is not surprising that the design flood values for several dams in India have been increased as a result of the occurrence of another record breaking flood. There is a perception that however big recorded floods become, that there will always be a bigger one in the future. This shows a failure to predict a reasonable value for the PMP and thus PMF for a safe spillway design.

We have recently presented a further paper at the Conference on Extreme Floods which was held at Reykjavik in 2000 in which the design standard of the Ukai and Lakhwar dam sites are shown to be only 50% of their safe value. Our results are supported by flood frequency analyses using a modified Gumbel Scale which has similarities to the Logistic Gumbel scale recently introduced by the Flood Studies Team at the Centre for Ecology and Hydrology at Wallingford (Centre for Ecology and Hydrology, 1999). We gave an example of the modified Gumbel scale in Rakhecha & Clark (1999a) using rainfall data. It also gives comparable results when applied to runoff data. For example at the Lakhwar dam site in Uttar Pradesh the results of three different methods of estimating the PMF are:

- Flood frequency analysis 12100 cumecs
- Rational method using Rakhecha & Clark PMP 14000 cumecs
- Instantaneous Unit hydrograph 18700 cumecs

It should not be assumed that a 50% difference between the highest and lowest values is a poor reflection of the methods. Predicting extreme events is always fraught with problems such as a lack of data and not enough freeboard built into the resulting design. Rainfall data spanning 100 years is only 1/10000 the length needed to give a reasonable estimate of the PMP. We also pointed out the tragedy of the Macchu dam failure in 1979. The following gives the dates of dam failures in India (Mistry, 1993).

- Kaddam 1988
- Panshet 1961
- Khadakwasia 1961
- Chikkhole 1972
- Mitti 1988

When all is considered the provision of safe dams for the people of India must remain as the highest priority. Our philosophy can be summed up by the words of Mistry (1993): 'The projects are built for the welfare of the humankind and should be made safer by introducing the latest design criteria and the design parameters be based on the latest hydrological data...' Finally, our atlas of PMP for 1, 2 and 3-day PMP (Rakhecha, & Clark, 1999b) includes details of both latitude and longitude and is available from Charldon Hill Research Station (CHRS). Prof. Hardaker has recently reviewed the atlas in the January 2000 edition of *Weather*, published by the Royal Meteorological Society.

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