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Difference between rainfall catches recorded in shallow and deep rim raingauges

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1. Introduction

According to Middleton and Spilhaus (1953), it has been "shown beyond reasonable doubt that of two raingauges having the same diameter, the one with the deeper rim catches the most rain, presumably because some of the drops splash out of the shallower funnel.....The Meteorological Office (London) is entirely correct in recommending the abolition of gauges with shallow rims, since it seems more probable that the shallow rim would *lose* rain by splashing out, than that the deeper rim would *collect*, any water that does not belong to it". The investigations carried out by Kadel (1930) during 1923-25, did not conclusively prove this. He compared two U.S. 8 in. gauges, one having the vertical wall of the funnel of 2¼ in. and the other 6 in. deep. 97 observations from May to October 1923 gave an increase of 1·4 per cent in the rainfall catch in the deeper rim gauge. 145 comparative observations from May 1924 to March 1925 showed a greater catch in the 6 in. deep funnel by 1·2 per cent. While the catch was more in strong winds than in moderately windy weather, the differences were not significant. Though the number of comparisons were too few for arriving at any definite result, he concluded that increasing the 2¼ in. depth of the funnel of the 8 in. gauge to 6 in. increased the amount by a little more than 1 per cent, a value within the limits of error and that there was no sufficient warrant for correcting the existing records or recommending a change in the U.S. gauge.

Denison (1941) compared the amount of precipitation collected in a standard Canadian raingauge and a U.S. gauge for 6 months from September 1939 to February 1940 and found that the Canadian gauge with a deeper rim recorded more rainfall. In observations at two stations, the deeper rim gauge was found to record 2·3 per cent and 2·9 per cent more than the U. S. gauge but the difference was less in windy weather.

The C.I.M.O. (WMO, No. 8 TP. 3, 1950) has recently recommended that "The wall of the collector should be deep to prevent rain from being blown out by wind and from splashing it out. A depth about equal to the diameter of the collector is suitable".

The C.I.M.O. Working Group on the measurement of rainfall and the Committee on Precipitations of the U.G.G.I. at their 1955 meeting in Zurich, reported:

"When rainfall is heavy, a raingauge whose lower walls are not sufficiently sloped, gives rise to splashing, as a result of which part of the water which has entered the instrument leaves it again in the form of a mist of fine droplets, thus causing a significant loss of water".

"In case the rain is accompanied by a very strong wind, such as with tornadoes, the cross-section of the raingauge should be designed to minimize splashing".

"In principle the trajectory of all drops should meet the inner wall at an angle greater than 90°, if possible, and in any case never less than 90°. The diagram shows possible solutions with $\alpha > 90°$" —see Fig. 1.

"It should be pointed out that the meridianal section with a constant angle is the arc

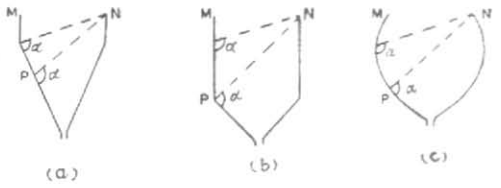

Fig. 1

of a logarithmic spiral. Of these solutions, the diagrammatic shapes (a) and (b) give rise simultaneously to both outward splash at M and inward splash at N; it is probable however that the outward splash at M greatly exceeds the inward splash at N, part of the latter being carried beyond the opening by the wind. Shape (c) greatly reduces outward splash, but increases inward splash".

The standard 5 in. raingauge of the India Meteorological Department, which has now been in use in India for nearly a hundred years has a shallow rim. The funnel is only $1\frac{1}{2}$ in. below the rim, *i.e.*, just over a quarter of its diameter. In order to determine the corrections, if any, due to the splashing of drops during very heavy rain or thundershowers, a series of comparisons were carried out at a number of stations in India during the period 1929—1950 between standard (India Meteorological Department) gauges and gauges with the funnel about 5 in. below the rim. The present paper deals with the results obtained.

2. Observations

(*i*) The first comparison at Poona during 1929 and 1930 was between an IMD raingauge and a Snowdon gauge of the United Kingdom. In the latter gauge, the upper edge of the funnel is nearly one diameter below the rim assuring an angle of impact of the rain drops of 90°, which is on the average sufficiently close to the logarithmic spiral of 110°.

(*ii*) The comparisons carried out at Alipore, Calcutta from 1935 to 1937 were the most accurate and detailed of the series. The two raingauges were erected with the rims one foot above ground level, six feet apart and in a line at right angles to the prevailing direction of the wind during the monsoon. The rain collected in both gauges was measured with the same measure-glass provided with an NPL certificate.

The IMD and British gauges were first compared for a period of two years from October 1935 to October 1937. To ascertain whether any systematic errors exist between observations from two identical gauges, two IMD gauges were installed at exactly the same sites where the IMD and British gauges had been installed earlier and comparative observations were taken from March 1938 to February 1939—Table 2(b). The two gauges were interchanged after this to see if there was any effect due to exposure, and the observations repeated for 5 months—Table 2(c).

The diameters of the funnels of the IMD and British gauges were checked and found to differ by only 0·003 in. The error caused by differences in inclination to the horizontal was found to be less than 0·03 per cent.

(*iii*) To check the results of these observations at Calcutta, observations were repeated at Colaba (Bombay) for 19 months from June 1940 to December 1941 and at Jubbulpore in Central India from June 1940 to February 1941. Still later, comparative observations were taken at Poona and Mahabaleshwar from October 1948 to October 1950 with a standard IMD gauge and a deep rim gauge where the funnel was 5 in. below the rim.

Table 1 gives the results of the first comparison between IMD and British gauges during the two monsoons of 1929 and 1930 at Poona.

Tables 2(a), 2(b) and 2(c) give the results of the series of comparisons made at Alipore.

Tables 3, 4, 5 and 6 give the results of the comparative observations at Colaba, Jubbulpore, Poona (1948—50) and Mahabaleshwar.

For a complete understanding of the results of the comparisons it would have been advantageous to present *in toto* the tabulated measurements of rainfall as reported. However, due to shortage of space the observations have been summarised as in the Tables 1 to 6.

.Discussion of Results

1. Poona (1929—1930)

During a period of 16 months, when a total rainfall of 48 inches was recorded, the deep rim raingauge collected 0·49 in. more than the shallow one. The individual rainfall amounts were however small, being less than half an inch on 164 out of 191 occasions. Of the 191 observations, 125 showed exact agreement between the two gauges, while on 49 occasions the deep rim gauge collected more rain and on 17 occasions less. The differences in catch were small, being only 0·01 in. on 50 occasions, 0·02 in. on 9 occasions, 0·03 in. on 3 occasions and 0·04, 0·06, 0·07 and 0·14 in. on one occasion each. As the mean difference is significant for all observations combined, it may be concluded that the deep rim gauge collected 1 per cent more rain than the shallow one.

2. Alipore (1935—1937)

(*a*) A total rainfall of about 140 inches was recorded during the period of observations at Alipore, the deep rim gauge recording 4·11 inches more than the shallow rim. *On no occasion did the shallow rim gauge collect more rain than the deep rim one.* Of the 248 observations, 70 showed exact agreement between the two gauges, 92 showed a difference of 0·01 in., 40 a difference of 0·02 in., 15 a difference of 0·03 in., 7 a difference of 0·04 in., 8 a difference of 0·05 in., 6 a difference of 0·06 in., 4 a difference of 0·07 in., 2 a difference of 0·08 in. and 1 a difference of 0·10, 0·12 and 0·14 in. each. The difference in catch was of the order of 0·01 in. for rainfall amounts of half inch and less, 0·02 to 0·03 in. for rainfall from 1/2 to 1 in., and as much as 0·08 to 0·14 in. for higher rainfalls of 3 to 5 in. On an average the deep rim gauge collected 3 per cent more rain than the shallow one, this difference occurring consistently for all rainfall amounts.

(*b*) *Differences due to exposures*—A study of the effect of exposure on the catch of two similar gauges proved to be of interest. Two IMD gauges installed at sites X and Y and compared during 1937-38 showed that the gauge at site Y collected more rain than the gauge at X. The number of observations was 124 and the percentage difference 1·6. The gauges were then interchanged and 91 observations taken during the monsoon season of 1939. The gauge at site Y again recorded more than that at X, the percentage difference being 0·8. The gauge at site Y thus collected about 1 per cent more rain than the gauge at site X.

3. Colaba (1940—1941)

During a period of eighteen months at Colaba when the two gauges were compared, a total rainfall of 137 inches was recorded, the deep rim gauge collecting only 0·07 in. more rain than the shallow rim one. Of the 181 observations, 117 showed exact agreement between the two gauges, while on 27 occasions the deep rim gauge collected more rain and on 37 occasions less. 32 observations showed a difference in catch of 0·01 in., 16 showed a difference of 0·02 in., 4 a difference of 0·03 in., and 2 of 0·04 in. Though the rainfall amounts varied up to 7 in., none of the differences was statistically significant.

4. Jubbulpore (1940—1941)

81 inches of rainfall was recorded during the 15 months of comparative observations at Jubbulpore, but the total difference in catch was only 0·04 in. Of the 159 observations, 129 showed exact agreement between the two gauges, 24 showed a difference of 0·01 in. and only 6 of 0·02 in. The deep rim gauge collected more rain on 14 occasions and less on 16 occasions. The differences were extremely small and not statistically significant.

TABLE 1

Station : POONA

Comparative observations between (A) IMD raingauge—shallow rim and (B) Snowdon raingauge—deep rim

Number of observations	191	Difference A—B	—0·49 in.
Period	8-6-1929 to 5-10-1929	Difference as % of A	1·03
	22-5-1930 to 6-12-1930	Mean difference of 191 observations A—B	—0·003 in.
Total rain collected in A	47·44 in.	Standard error	0·010
Total rain collected in B	47·93 in.	Standard error of the mean	0·0008

$t = 3·37$ (significant)

Rainfall intervals (inches)	No. of observations n	Mean difference m=A—B	Standard error σ	Standard error of mean σ_m	$t=m/\sigma_m$
0·01 to 0·50	164	—0·002	0·007	0·0005	4·4
0·51 to 1·00	14	0·006	0·019	0·0051	1·1
1·01 to 2·00	11	—0·016	0·023	0·0070	2·3
>2·00	2	—0·02	..	..	..

TABLE 2(a)

Station : ALIPORE

Comparative observations between (A) IMD raingauge at site X—shallow rim and (B) Snowdon raingauge at site Y—deep rim

Number of observations	248	Difference A—B	—4·11 in.
Period	1-10-1935 to 30-9-1937	Difference as % of A	2·98
	(2 years)	Mean difference of 248 observations A—B	—0·017 in.
Total rain collected in A	137·71 in.	Standard error	0·021
Total rain collected in B	141·82 in.	Standard error of the mean	0·0013

$t = 12·8$ (significant)

Rainfall intervals (inches)	No. of observations n	Mean difference m=A—B	Standard error σ	Standard error of mean σ_m	$t=m/\sigma_m$	5 per cent value of t
0·01 to 0·50	171	—0·007	0·007	0·0005	14·0	1·97
0·51 to 1·00	35	—0·021	0·013	0·002	10·5	2·0
1·01 to 2·00	29	—0·040	0·017	0·003	13·3	2·1
2·01 to 3·00	5	—0·056	0·014	0·006	9·3	2·8
>3·00	8	—0·086	0·035	0·012	7·2	2·4

TABLE 2 (b)

Station : ALIPORE

Comparative observations between (A) IMD raingauge No. 02567 at site X—shallow rim and (B) IMD raingauge No. 03667 at site Y—shallow rim

Number of observations	124	Difference A—B	—0·77 in.
Period	1-3-1938 to 28-2-1939	Difference as % of A	1·62
	(1 year)	Mean difference of 124 observations A—B	—0·006 in.
Total rain collected in A	47·58 in.	Standard error	0·011
Total rain collected in B	48·35 in.	Standard error of the mean	0·001

$t = 6 \cdot 5$ (significant)

Rainfall intervals (inches)	No. of observations n	Mean difference m=A—B	Standard error σ	Standard error of mean σ_m	$t=m/\sigma_m$	5 per cent value of t
0·01 to 0·50	97	—0·004	0·006	0·0007	5·7	2·0
0·51 to 1·00	14	—0·001	0·012	0·0033	3·3	2·2
1·01 to 2·00	9	—0·017	0·019	0·0063	2·7	2·3
2·01 to 3·00	2	—0·015	..	..	..	..
>3·00	2	—0·020				

TABLE 2 (c)

Station : ALIPORE

Comparative observations between (A) IMD raingauge No. 03667 at site X—shallow rim and (B) IMD raingauge No. 02567 at site Y—shallow rim

Number of observations	91	Difference A—B	—0·51 in.
Period	May to Sep 1939	Difference as % of A	0·79
	(5 months)	Mean difference of 91 observations A—B	—0·0056 in.
Total rain collected in A	64·79 in.	Standard error	0·015
Total rain collected in B	65·30 in.	Standard error of the mean	0·0016

$t = 3 \cdot 5$ (significant)

Rainfall intervals (inches)	No. of observations n	Mean difference m=A—B	Standard error σ	Standard error of mean σ_m	$t=m/\sigma_m$
0·01 to 0·50	50	0·001	0·006	0·0009	1·1
0·51 to 1·00	15	0·003	0·017	0·0045	0·7
1·01 to 2·00	19	0·012	0·020	0·0046	2·6
2·01 to 3·00	3	0·020	0·016	0·0093	2·2
>3·00	4	0·033	0·011	0·0055	6·0

TABLE 3

Station : COLABA

Comparative observations between (A) IMD raingauge with $1\frac{1}{2}$" rim and (B) IMD raingauge with 5" rim

Number of observations	181	Difference A—B	—0·07 in.
Period	4-6-1940 to 31-12-1941	Mean difference as % of A	0·05
		Mean difference of 181 observations A—B	—0·0004 in.
Total rain collected in A	137·27 in.	Standard error	0·029
Total rain collected in B	137·34 in.	Standard error of the mean	0·002

$t = 0·18$ (not significant)

Rainfall intervals (inches)	No. of observations n	Mean difference m=A—B	Standard error σ	Standard error of mean σ_m	$t=m/\sigma_m$
0·01 to 0·50	125	—0·0002	0·0041	0·0004	0·43
0·51 to 1·00	15	—0·002	0·0115	0·0030	0·60
1·01 to 2·00	19	0·004	0·0310	0·0072	0·61
2·01 to 3·00	8	0·007	0·0221	0·0078	0·90
>3·00	14	0·024	0·1005	0·0027	0·24

TABLE 4

Station : JUBBULPORE

Comparative observations between (A) IMD raingauge with $1\frac{1}{2}$" rim and (B) IMD raingauge with 5" rim

Number of observations	159	Difference A—B	0·04 in.
Period	1-6-1940 to 23-8-1941	Mean difference as % of A	0·05
		Mean difference of 159 observations A—B	0·0003 in.
Total rain collected in A	80·57 in.	Standard error	0·0056
Total rain collected in B	80·53 in.	Standard error of the mean	0·0004

$t = 0·57$ (not significant)

Rainfall intervals (inches)	No. of observations n	Mean difference m=A—B	Standard error σ	Standard error of mean σ_m	$t=m/\sigma_m$
0·01 to 0·50	109	—0·005	0·001	0·0010	0·48
0·51 to 1·00	28	—0·001	0·006	0·0011	1·2
1·01 to 2·00	18	—0·002	0·001	0·0002	..
2·01 to 3·00	1	0	..	..	..
>3·00	3	0·003	0·002	0·0011	..

TABLE 5

Station: POONA

Comparative observations between (A) IMD raingauge with $1\frac{1}{2}''$ rim and (B) IMD raingauge with $5''$ rim

Number of observations	192	Difference A—B	—0·04 in.
Period	1-10-1948 to 31-10-1950	Difference as % of A	—0·7
		Mean difference of 192 observations A—B	—0·00021 in.
Total rain collected in A	59·83 in.	Standard error	0·0039
Total rain collected in B	59·87 in.	Standard error of the mean	0·0003

$t = 0·74$ (not significant)

Rainfall intervals (inches)	No. of observations n	Mean difference m=A—B	Standard error σ	Standard error of mean σ_m	$t=m/\sigma_m$
0·01 to 0·50	159	0·0001	0·003	0·0002	0·56
0·51 to 1·00	16	—0·0012	0·005	0·0012	1·00
1·01 to 2·00	14	—0·0023	0·004	0·0012	1·88
2·01 to 3·00	3	—0·0133	0·012	0·0095	1·97

TABLE 6

Station: MAHABALESHWAR

Comparative observations between (A) IMD raingauge with $1\frac{1}{2}''$ rim and (B) IMD raingauge with $5''$ rim

Number of observations	304	Difference A—B	0·73 in.
Period	1-10-1948 to 31-10-1950	Difference as % of A	0·17
		Mean difference of 304 observations A—B	0·0024 in.
Total rain collected in A	429·34 in.	Standard error	0·031
Total rain collected in B	428·61 in.	Standard error of the mean	0·0018

$t = 1·33$ (not significant)

Rainfall intervals (inches)	No. of observations n	Mean difference m=A—B	Standard error σ	Standard error of mean σ_m	$t=m/\sigma_m$
0·01 to 0·50	130	—0·003	0·008	0·0007	3·53
0·51 to 1·00	59	—0·005	0·0096	0·0012	4·32
1·01 to 2·00	52	—0·001	0·0161	0·0023	0·26
2·01 to 3·00	18	0·002	0·0432	0·0102	0·17
3·01 to 4·00	18	0·015	0·0349	0·0082	1·82
4·01 to 5·00	9	0·014	0·0198	0·0066	2·12
>5·00	18	0·005	0·0914	0·0215	2·55

5. Poona (1948—1950)

During a period of 24 months when comparative observations between deep and shallow rim gauges were repeated at Poona the deep rim raingauge collected only 0·04 in. more than the shallow rim gauge. On 168 occasions out of 192, no difference in catch was recorded. On 15 occasions the deep rim collected more and on 9 occasions less, but the differences were small, being only 0·01 in. on 24 occasions and 0·02 in. on 6. The mean difference in catch was only 0·07 per cent and statistically not significant.

6. Mahabaleshwar (1948—1950)

A total rainfall of 429 inches was recorded during the period of comparative observations. Of these, on 174 occasions the rainfall was more than half an inch. The differences in catch were however small. On 137 occasions out of 304, the two gauges collected the same rainfall. On 115 occasions the deep rim raingauge recorded more than the shallow rim and on 52 occasions less. But these latter were the occasions of heavy rainfall and the difference in catch larger. The total difference in rainfall catch as a percentage was, however, only 0·2 per cent and the mean difference of no statistical significance.

4. Conclusion

The early observations at Poona and Alipore showed definitely that shallow rim raingauge collects less rain than the deep rim one. The later experiments at Poona and at Colaba, Jubbulpore and Mahabaleshwar did not confirm this or establish the advantage of the deeper funnel over the shallow one. In view of the inconclusive results, the statement in the opening sentence of this paper calls for a re-examination of the problem, whatever the theoretical justification for it may be.

5. Acknowledgement

The analysis of the data in Table 2 was done by Shri V. Satakopan in 1940 and the data have been taken from the office records. I am thankful to Shri K. Raja Rao for the analysis of data in the other tables.

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