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Studies on Forecasting Local Rainfall in India with the help of Precipitation Index

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Editorial note.—Messrs. D. V. Rao, V. Vittal Sarma and S. S. Lal submitted papers for departmental publication on forecasting local precipitation by Schell's method at Madras, New Delhi and Nagpur on 23rd December 1947, 1st March 1948 and 25th May 1948 respectively. As all these papers have analysed the radio-sonde data in a similar manner, they have been combined into one paper under the title "Studies on Forecasting of Local Rainfall in India with the help of Precipitation Index." Although the results obtained differ from Schell's for the U. S. A. and also to some extent among themselves, they are of interest as showing the potentialities of the method for local forecasting. Before however, arriving at general conclusions applicable to the whole country, it appears necessary to examine the radio-sonde data by this method for a few more representative stations in the country.

Introduction.

I. I. Schell in a paper published in the Bulletin of the American Meteorological Society in 1946 (Single-Radiosonde Analysis in Local 8-hr. forecasting of precipitation) has indicated a method of using the radio-sonde ascents for forecasting precipitation during subsequent eight hours at the station. As the method is applicable without necessarily using synoptic charts, it could be of great value for local forecasts covering areas around radio-sonde stations. The method itself is fairly simple and consists in evaluating the precipitation index $I = \Sigma \frac{w}{L}$ where w is the mixing ratio and L the pressure fall during ascent to the saturation level in units of Cb (1 Cb = 10 mb), for layers up to 600 mb. The details of the working, with an example, are given in Schell's paper referred to above. The present paper is divided into three sections dealing with the analysis by Schell's method of radio-sonde data of Madras, New Delhi and Nagpur respectively. The values of the precipitation index have been calculated for the available ascents at these three places, for the periods considered and compared with the subsequent precipitation in twelve hours at Madras and Nagpur and thirteen hours at New Delhi. The rainfall amounts were taken from the Monthly Meteorological Registers and/or autographic charts of the stations for comparison.

1. Madras.

Madras normally gets 50·7 inches of rain in a year of which as much as 41·4 inches (82%) is received in the period August to December. This period also contains 41 out of the total of 57 rainy days in the year and is thus the rainiest at Madras. All available radio-sonde data during the rainy period August to December 1946 as well as in the first half of January 1947 when some thundershowers had been recorded, were analysed. During the period, there were 131 days for which the index could be evaluated. On the rest of the 37 days either there were no ascents or they were too short or were doubtful and unreliable.

A period of 12 hours following the ascents was taken into consideration for determining the probability of rain instead of the 8-hour period adopted by Schell in the U. S. A. where more frequent ascents are made. A longer period would also increase the usefulness of this method of forecasting precipitation.

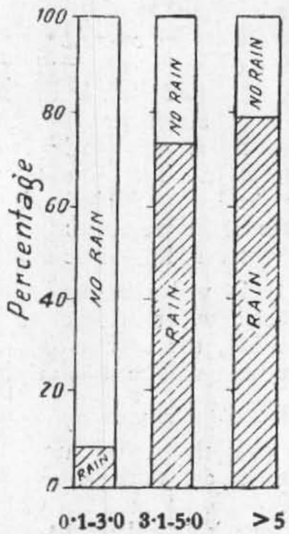
TABLE I.

Number of occasions of rain and no rain within 12 hours of ascent.

Precipitation Index (gm./kgm.)/cb.	Total no. of occasions.	Number of occasions of rain.										Total no. of occasions of rain.
		Trace—0.25"	0.26—0.50"	0.51—1.00"	1.01—2.00"	2·01—3.00"	3.01—4.00"	4.01—5.00"	5.01—6.00"	6.01—7.00"	7.01—8.00"	
0.1—1.0	6	0	0	0	0	0	0	0	0	0	0	0
1.1—2.0	26	1	0	1	0	0	0	0	0	0	0	2
2.1—3.0	31	2	0	0	0	0	0	0	0	0	0	2
3.1—4.0	17	6	1	1	2	1	1	0	0	0	0	12
4.1—5.0	13	4	3	2	1	0	0	0	0	0	0	10
5.1—6.0	13	6	0	1	1	1	2	0	0	0	0	11
6.1—7.0	7	2	0	2	0	1	0	0	0	0	0	5
7.1—8.0	6	3	0	0	0	0	1	0	0	0	0	4
8.1—9.0	7	2	0	2	1	0	0	0	0	0	0	5
9.1—10.0	1	1	0	0	0	0	0	0	0	0	0	1
10.1—11.0	2	1	0	1	0	0	0	0	0	0	0	2
11·1—12.0	2	0	1	0	0	0	0	0	0	0	1	2

The values of the index evaluated ranged from ·1 to 12·0. Table I above gives the distribution of the index with reference to subsequent rainfall amounts in 12 hours.

It is seen from the table that when the Index was less than 1 there was not a single case of precipitation. When the index was 1·1—3·0, there were only four cases out of 56, or only 7% of occasions of subsequent rainfall. When the index was more than 3, 77% of all occasions were followed by rain in 12 hours. The different ranges of the index and the associated frequency of rainfall are shown in Fig. 1.



Precipitation Index I_{600}

Fig. 1. MADRAS

Exceptions to dry weather when the index was 1·1—3·0.

All the 4 occasions of occurrence of precipitation when the index was 1·1— 3·0 were in the month of November. The values of the index on these four occasions were 1·1, 1·3, 2·2 and 3·0. The month of November is the rainiest at Madras. Advection of moisture can and does take place in this month with considerable rapidity, even within a period of 12 hours. That would result in a quick rise in the humidity mixing ratio in the atmosphere. On these four occasions in November, it is probable that, after the ascent was made, the thermodynamic situation in the atmophere may have greatly altered. On such occasions, a careful study of the synoptic situation is necessary before forecasting dry weather in the next 12 hours It may therefore be generally stated that, except in the month of November, there are no cases of any rain at Madras within 12 hours of the radio-sonde ascent giving an index of less than or equal to 3. And even in November, a forecast of dry weather when the index is less than 3, made without reference to the synoptic situation, would have a very high chance of proving correct.

Exception to rainfall when the Index was greater than 3·0.

The monthly distribution of the anomalous cases of no rain occurring even when the index was greater than 3 is shown in Table II.

TABLE II.

Number of occasions of dry weather during August to December.

Index gm./kgm /cb.	Total No. of occasions.	Number of occasions of no rain.				
		August.	September.	October.	November.	December.
3·1—5·0	29	1	2	2	2	1
5·1—7·0	17	2	2	0	0	0
> 7·0	16	2	0	2	0	0

Of the above 5 cases in August when there was no rain with an index greater than 3, two had an index of more than 7. But these ascents were made after some precipitation had already taken place. The air was thus humid and yielded a high value for the index.

All the 4 cases of no rain in the month of September were of ascents made in the wake of thundery activity or thundershowers at the station or closeby. The high value of the index in these cases therefore loses its prognostic significance. Similar are the two cases in October with index greater than 7, both the ascents having been made after moderate to heavy falls of rain at the station. On the remaining two occasions in October and on the two occasions in November, the moist air at the time of the ascent was rapidly replaced by dry land air, this transitional period at Madras being one of swift and sweeping changes. On the one occasion in December when a high index was not followed by rain, an examination of the tephigram showed that the air was nearly saturated in the lower levels up to 850 mb. but was extremely dry aloft. The synoptic situation on that day did not warrant the possibility for the extension of moisture to the higher levels. The high value for the index in this case therefore ceases to have any prognostic value. The precipitation index dropped to the very low value of 0.8 on the following day.

It will thus be seen that, if we do not attach too much value to ascents made after the occurrence of afternoon or evening thundershower at or close to the station, the chances are great that a precipitation index of more than 3 in the late evening will be followed by rain within the succeeding twelve hours.

Percentage frequency of the index ranges associated with rain in different months.

Of the period under study, August and September are representative of the southwest mosoon conditions and October and November of the post-monsoon transitional months yielding place to the northeast monsoon in the months of December and January. The distribution of the ranges of the index associated with rain in these various seasons and the percentage frequency of each range of the index in each season are given in Table III.

TABLE III.

Index (gm./kgm.)/cb.	No. of occasions.	Amount of rainfall in 12 hours.		
		Trace—0·25"	0·26—1·00"	>1"
		August-September.		
1·1—3·0	0 0%	0 0%	0 0%	0 0%
3·1—5·0	9 70%	5 56%	2 22%	2 22%
> 5·0	4 30%	3 75%	1 25%	0 0%
		October-November.		
1·1—3·0	4 11%	3 75%	1 25%	0 0%
3·1—5·0	12 41%	4 33%	5 42%	3 25%
> 5·0	13 45%	6 46%	3 23%	4 31%
		December-January.		
1·1—3·0	..	..	..	..
3·1—5·0	1 7%	1 100%	0 0%	0 0%
> 5·0	13 93%	6 46%	3 23%	4 31%

This table shows that the frequency of the higher ranges of the index associated with rain increases with the advance of the season.

Schell states in his paper that, in the application of the index to other areas and seasons than those tested by him, it should be expected that the critical limiting value between precipitation and no precipitation groups would be much the same, provided the circulation is similar to that of northeastern U. S. A. in the cold season. The limiting value of the index associated with rain in Madras is 3, while in the U. S. A. it is only 1. This can be explained as being due to the higher moisture content of the air in the tropics, because of the higher virtual temperatures that obtain there. It may therefore be more correct to say that the higher the mean virtual temperature of the air that prevails over a place, the greater should be the limiting value of the index in order to give an identical chance for the occurence of precipitation.

The Intensity of rainfall in relation to the magnitude of the precipitation Index.

Table III shows the association between the intensity of rainfall and the magnitude of the index in the periods August-September, October-November and December-January.

Even an index of more than 3 is associated with light showers in the monsoon and winter seasons. For the same range of the index, the rainfall is more intense in the monsoon months than in the winter period. Thus, a higher value for the precipitation index would not *ipso facto* mean a larger amount of rainfall, irrespective of the season of the year as stated by Schell, whose investigations were confined to the cold season in the northeast U. S. A. The amount of rainfall associated with any particular index would vary from season to season.

Conclusions.

The above discussion shows that the precipitation index by itself can be used for forecasting local weather at Madras without reference to the synoptic situation over an area, with a fair measure of success. A study also of the synoptic situation and the upper air characteristics, where possible, would help one to give, more reliable forecasts regarding local weather within a period of 12 hours subsequent to the time of the sounding.

2. New Delhi.

Daily Radio-sonde observations taken at New Delhi during June to September of 1945 and 1946 have been used in this analysis. The number of ascents available was 111 in 1945 and 113 in 1946. The observations were generally taken between 1830 hrs. I. S. T. and 2030 hrs. I. S. T. The 'precipitation index' for each day was calculated in the same way as in Schell's article. The 'precipitation index' was also calculated in the same manner for each ascent restricting the layers of atmosphere up to 800 mb. level and 700 mb. level separately so as to judge their utility when the ascents do not extend up to 600 mb. Thus, three values of precipitation index (I) were calculated for each ascent : I_{800}, I_{700}, I_{600}.

The rainfall data were obtained from the Monthly Meteorological Registers of the New Delhi observatory. The rainfall amount for the period 1700 hrs. I. S. T. to 0800 hrs. I. S. T. next morning together with their times of occurrence were tabulated against the values of precipitation index for each day. In a few cases where the time of ascent of radio-sonde observations were later than usual, occurrence of precipitation after 0800 hrs. I. S. T. of the next morning, but before an expiry of 13 hrs. from the time of observation have also been taken into consideration. Also there were some cases in which rainfall occurred just at the time of observations or before the time of 'raob.' Such cases, have been omitted from the final analysis because it was considered that the precipitation preceding the time of observation would have influenced the value of the index. After omitting these cases there were in all 203 ascents. Out of these only 192 went up to 700 mb. level and 138 up to 600 mb. level.

The following Table IV shows frequencies of occurrence of precipitation index and subsequent rainfall in 13 hrs. grouped according to the classification (1) No rain (2) Trace (3) 0·1 to 1 inch and (4) Greater than 1 inch. In the last column is shown the percentage probability of occurrence of rainfall for the different ranges of the precipitation index.

TABLE IV.

Frequency distribution of rainfall corresponding to different ranges of the Precipitation Index.

Precipitation Index.		No. of occasions of				Percentage No. of occasions of rain.
		No rain.	Trace.	0·1" to 1·0".	> 1·0".	
I_{800}	0·1—2·0	85	3	8	1	12
	2·1—6·0	51	9	15	2	34
	> 6·0	8	2	17	2	72
I_{700}	0·1—2·0	81	1	7	1	10
	2·1—6·0	52	10	16	1	34
	> 6·0	5	1	16	1	78
I_{600}	0·1—2·0	57	4	5	1	15
	2·1—6·0	35	6	10	2	34
	> 6·0	3	2	13	..	83

It is seen from the table that I_{600} gives a better indication of the chances of precipitation than those for lower levels.

A critical value of the precipitation index is to be fixed above which the chances of rainfall occurring should be high so that the precipitation index may be used for forecasting local rainfall. Schell has found that 3 is the critical value for the observations he has discussed. It is however found from the table that 3 or even 4 may be too low a value for use as a critical value.

The chance of occurrence of rainfall is five to one (83 : 17) when I_{600} is greater than 6. When I_{600} is between 2 to 6, the chances are 1 to 2. For less than 2 the chance of rainfall is negligible being only 15 per cent. A critical value of 6 appears to be suitable to indicate high probability of rainfall during the succeeding 13 hours at New Delhi.

The results are illustrated in Fig. 2.

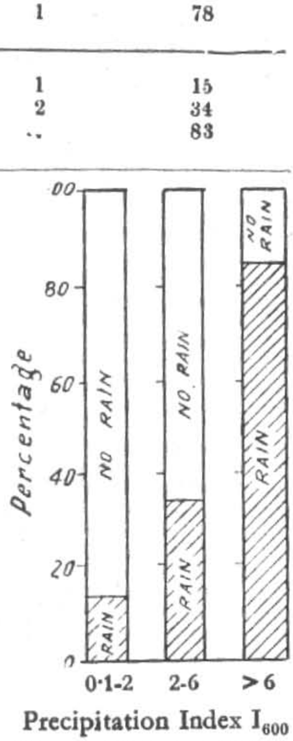


Fig. 2. NEW DELHI

3. Nagpur.

In this section radio-sonde data of Sonegaon Airfield, Nagpur, have been analysed.

Nagpur, the capital of the Central provinces and Berar is situated almost in the centre of India, about 40 miles to the south of the Satpura range, a belt of hills and plateau which crosses India near the Tropic of Cancer. The Sonegaon Airfield (Lat. 21°06′, Long. 79°03′, height above Mean Sea Level 1020 ft.) lies at about 4½ miles to the SSW of Nagpur City. There are no marked orographical features in the vicinity of the airfield.

For the purposes of forecasting rainfall by Schell's method, the 12-hour period following a radio-sonde ascent has been taken into consideration. The 'Precipitation Index' was worked out for Radio-sonde ascents during March and June to October 1947. The reasons for selecting this period for investigation were :—

(*a*) March—A dry month, with occasional thunderstorm activity.

(*b*) June—September—Monsoon months, being the rainiest period.

(*c*) October—A dry autumn month.

The daily ascents were generally made between 1900 and 2000 hrs. IST. In all 152 ascents have been analysed.

Discussion of Results :

(*a*) *Characteristics of index-values* :—

I varied from 0·1 to 13·0. Table V gives the number of cases in each month arranged under different ranges of index values (0·0—0·5, 0·6—1, 1·1—1·5, etc.) together with the corresponding number of occasions of precipitation.

TABLE V.

Showing ranges of indices in the different months of 1947 at Nagpur with occasions of precipitation

Index. / Months.	0·0 to 0·5	0.6 to 1·0	1·1 to 1·5	1·6 to 2·0	2·1 to 2·5	2·6 to 3·0	3·1 to 3·5	3·6 to 4·0	4·1 to 4·5	4·6 to 5·0	5·1 to 5·5	5·6 to 6·0	6·1 to 6·5	6·6 to 7·0	7·1 to 7·5	7·6 to 8·0	8·1 to 8·5	8·6 to 9·0	9·1 to 9·5	9·6 to 10·0	10·1 to 10·5	10·6 to 11·0	11·1 to 11·5	11·6 to 12·0	12·1 to 12·5	12·6 to 13·0	Total.
A—Dry months.																											
March—																											
(a) No. of cases ..	16	7	3	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	28
(b) Occasions of rain	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
October—																											
(a) No of cases ..	8	11	4	..	..	1	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	26
(b) Occasions of rain	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
B—Monsoon months.																											
June—																											
(a) No. of cases ..	6	6	6	3	..	..	3	..	1	..	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	27
(b) Occasions of rain	..	1	1	..	..	..	2	..	1	..	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	7
July—																											
(a) No. of cases ..	..	..	1	3	4	1	2	2	1	3	3	2	..	..	..	1	..	..	1	..	..	..	..	..	..	1	25
(b) Occasions of rain	..	..	..	1	1	.	1	2	1	2	3	2	..	..	..	1	..	..	1	..	..	..	..	..	..	1	16
August—																											
(a) No. of cases ..	..	..	1	2	4	3	3	1	2	2	..	1	..	..	3	..	1	1	..	1	..	..	..	..	..	..	25
(b) Occasions of rain	..	..	..	..	1	1	2	1	1	2	..	1	..	..	3	..	1	1	..	1	..	..	..	..	..	..	15
September—																											
(a) No. of cases ..	..	1	..	4	3	1	2	2	2	..	1	..	..	1	..	..	1	..	1	1	..	..	..	1	..	..	21
(b) Occasions of rain	..	1	..	..	1	1	2	1	1	..	1	..	..	1	..	..	1	..	1	1	..	..	..	1	..	..	13
Total—(a) No. of cases	30	25	15	13	11	7	11	6	6	5	4	3	1	1	3	1	2	1	2	2	..	1	..	1	..	1	152
(b) Occasions of rain	..	3	1	2	3	2	7	4	4	4	4	3	1	1	3	1	2	1	2	2	..	1	..	1	..	1	53

An examination of this table will show :—

(i) For I less than ·5 no cases of precipitation have been recorded in any of the months under consideration.

(ii) During March I did not exceed ·3 and during October 4·0. Moreover, nearly 98% of cases with 'no precipitation' fall within the range 0·1—1·5.

(iii) In July and August which are the rainiest months, no index values occur between 0·1 and 1·0.

(iv) During monsoon season (June—September), most of the index values fall within 10. There are only 3 cases with very high index values ranging between 10·1 and 13·0.

(v) Rainfall during the 12-hours period following the radio-sonde ascent has been recorded on practically all the occasions when the index value exceeded 5·0.

(b) *Applications to forecasting* :—

(i) *Possibility of precipitation* :—As may be expected, occasions with high index values (greater than 5) show a greater proportion of rainfall than ascents with moderate index-values.

TABLE VI.

Frequency distribution of rainfall corresponding to different values of the Precipitation Index.

Index group.	Occasion of				Percentage No. of occasions of rain.	Average amount of rainfall.
	No rain	Trace.	0"·01 to 0"·30.	>0"·30.		
Low (0·1—3·0)	90	2	9	..	11	..
Moderate (3·1—5·0).	9	4	10	5	68	0"·15
High (> 5)	..	4	9	10	100	0"·33

It is seen from table VI that all the 23 cases with I>5 were followed by precipitation. The occasions of rainfall associated with moderate index values (between 3·1—5·0) are naturally smaller, out of 28 cases, 19 being with precipitation (68%) and 9 without. The frequency distribution of precipitation for various index-groups is shown in Fig. 3.

With a low index (of 3·0 or less) the number of correct forecasts of 'no precipitation' during the 12-hours following an ascent would be about 90%. On the other hand, the number of correct forecasts of precipitation for appreciable index values (greater than 3) is 42 out of 51 cases, or 82%. For these two groups as a whole, the number of correct forecasts would be 132 out of 152 cases, or 87%.

(ii) *Amount of precipitation* :—

It may also be expected, that, on the whole, the precipitation following a high index value would be greater than that following a moderate index. For the moderate index group, the average rainfall is 0·15" and for high index group 0·33".

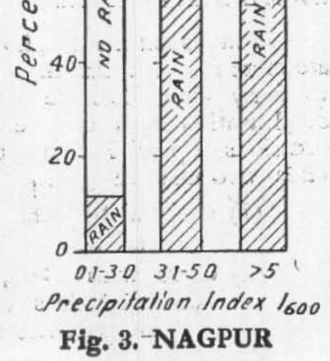


Fig. 3. NAGPUR

Conclusions :—

(1) I is very helpful in forecasting of precipitation within the 12 hours period after an ascent.

(2) With low index values (0·1—3·0), the chances for correct forecast of 'no precipitation' are 90%.

(3) With high index values (greater than 5) the chances for correct forecast of precipitation are 100 per cent.

(4) With moderate index values (3·1—5·0) the chances of correct forecast of precipitation are 68%.

(5) Precipitation following a high index value is usually greater than that following a moderate index value.

It will be noticed from table VII that practically all the cases of moderate to heavy precipitation are associated with index values greater than 5 and majority of them fall in July and August, which are actually the rainiest months of the south west monsoon period.

TABLE VII

Individual cases of rainfall of 0·5" and more at Nagpur with corresponding Index values.

Month.	Date.	Index value.	Amount of rainfall in 12 hrs. period following an ascent.
June, '47	9th	3·4	0·63"
	29th	10·8	0·65"
July, '47	12th	5·9	0·71"
	13th	7·7	0·50"
	15th	9·4	0·70"
	27th	5·4	1·35"
August, '47	16th	9·0	0·66"
	24th	10·0	0·58"
	28th	7·4	1·21"

(*c*) *General Remarks* :—

The values of precipitation index in the dry months (March and October) mostly fall under the low-index group.

In monsoon months, however, cases of precipitation with appreciable index-values are more frequent than those with low index values, the explanation being that due to fairly high moisture content of the atmosphere, the lift required to bring about condensation need not be high ; thus the values of ratio W/L are usually high. The occasions of precipitation in the monsoon months to corresponding index values fall under two main categories.

(1) Cases with index values between 3 and 5 give precipitation on 68% of occasions.

(2) Cases with I > 5, give precipitation on practically all occasions ; a few high index values were associated with traces (rainfall less than 0·01") and some with less than 10 cents of rain.

All cases which yield high-index values should give reasonable amount of precipitation, assuming that processes to give the required lift for condensation are readily available in the atmosphere. It is likely that under certain atmospheric conditions, the processes giving rise to instability or convergence may be present and are fully utilised ; in such cases the necessary lift will be available and therefore, the occurrence of precipitation is more or less definite and the amount of precipitation may be appreciable. There may also be occasions when the instability or convergence although adequate to produce lift to cause precipitation, may not be maintained. In these circumstances the precipitation occurs but in very small amounts. For example when precipitation has occurred within a couple of hours or so before the radio-sonde ascent, it is noticed that cases with high index values yield either a trace or very small amount of precipitation. In such cases, it can be assumed that the ascent of air had just ceased, and, therefore, the precipitation which otherwise could have been 'forecasted' by the index did not occur. Forecasting ' no ' precipitation following moderate or high index values, in cases of ascents which were started within about a couple of hours after moderate precipitation had ended, should therefore lead to a more correct forecast.