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An objective method of forecasting premonsoon thunderstorm/duststorm activity over Delhi and neighbourhood

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ABSTRACT. An attempt was made to provide an objective aid for forecasting of thunderstorm/duststorm in premonsoon season over Delhi and neighbourhood. Relationships of a number of meteorological parameters to subsequent convective activity were determined and the five parameters which showed the strongest relation ships were combined by graphical correlation techniques to form an objective forecast aid.

The method was tested on independent data and the results were found to be consistent with those obtained on the developmental data.

1. Introduction

An objective weather forecast as defined by Gringorten (1949) is a forecast that is made without recourse to the personal judgement of the forecaster. However, meteorology is much too complex to allow one to believe that objectivity in forecasting will, eventually, completely replace subjectivity. The advantages of objective forecasting are apparent. The graphical techniques used to relate the parameters to the element to be forecast enables a forecaster to issue a fairly accurate 'yes' or 'no' weather forecast and to state the probability of occurrence, if so desired. An additional advantage of objective aids is that if for some unforeseen reason a new forecaster is sent to the station on short notice, forecasts of weather element can be made by the new forecaster with the same accuracy as has been done in the past.

This study was initiated with the aim of providing an objective aid for forecasting thunderstorm/duststorm in premonsoon season over Delhi and neighbourhood. It was aimed at forecasting thunderstorm/duststorm activity in March, April May and June during the periods 1130 to 2330 and 2330 to 1130 IST of the following morning, the forecasts to be based on 0530 and 1730 IST data respectively.

2. Selection of data

To ensure that the thuderstorm/duststorm records used in developing the forecast procedure would be better representative of Delhi and neighbourhood, the following criteria were set up to decide if it was a thunderstorm/duststorm period.

1. A thunderstorm, duststorm and squall recorded by Observatory at Safdarjung Airport in New Delhi.

2. Thunderstorm cells of height 7 km or more within hundred kilometres around Delhi as reported in the radar observations of the station.

These criteria resulted in 337 periods, being designated as thunderstorm/duststorm periods of March, April, May and June during the 5-year period (1964-68), which comprised the devlopmental data upon which the study was based. Data for same months of 1969 and 1970 were reserved to test the procedure and referred to as independent or test data.

3. Selection of parameters

A number of meteorological parameters which are known to be useful in the problem of thunderstorm/duststorm forecasting were investigated to determine their relationship to thunderstorm/duststorm activity over Delhi and neighbourhood. The need to keep the procedure as simple and quick as possible was kept in view while selecting the parameters. The three parameters combined are detailed below—

(1) *Measures of instability and lower level moisture*

These consists of (*i*) Stability Index (Showalter), (*ii*) Convective condensation level corresponding to mean mixing ratio from surface to 850 mb, (*iii*) Difference in height of convective condensation level (CCL) and freezing level, (*iv*) Direction

TABLE 1

Relationship of stability index (Showalter) to the frequency of occurrence of thunderstorms/duststorms at Delhi

Stability Index	Total cases	No. of thunderstorms/duststorms	Frequency of occurrence of thunderstorms/duststorms (%)
>+4	234	12	5
+4	93	10	11
+ 3 to + 2	222	51	23
+ 1 to — 1	327	112	34
— 2 to — 4	238	115	48
< — 4	69	34	50

TABLE 2

Relationship of convective condensation level (CCL) to the frequency of occurrence of thunderstorms/duststorms at Delhi

Class intervals of CCL (mb)	Total cases	No. of thunderstorms/duststorms	Frequency of occurrence of thunderstorms/duststorms (%)
<550	135	12	9
551-600	253	42	17
601-650	369	100	27
651-700	225	81	36
701-750	120	48	40
751-800	58	33	57
>800	22	17	77

TABLE 3

Relationship of difference of height of convective condensation level (CCL) and freezing level (FL) to frequency of occurrence of thunderstorms/duststorms at Delhi

Class intervals of difference CCL—FL (mb)	Total cases	No. of thunderstorms/duststorms	Frequency of occurence of thunderstorms/(%)
<—50	97	6	6
— 50 to — 01	271	36	13
00 to 50	408	117	29
51 to 100	203	69	34
> 100	204	108	53

TABLE 4

Relationship of direction of thermal wind between 700-500mb to the frequency of occurrence of thunderstorms/duststorms at Delhi

Direction of thermal wind

	N	NNE	NE	ENE	E	ESE	SE	SSE	S
Total cases	44	58	20	41	45	68	49	44	61
No. of Thunderstorms/duststorms	11	17	4	10	13	29	19	13	13
Frequency of occurrence (%)	25	29	20	24	29	43	39	29	21

	SSW	SW	WSW	W	WNW	NW	NNW	Calm
Total cases	78	97	144	161	166	63	44	7
No. of thunderstorms/duststorms	20	36	37	26	48	16	16	2
Frequency of occurrence (%)	26	37	26	16	29	25	36	28

TABLE 5

Relationship of wind direction at 900 m at Delhi to the frequency of occurrence of thunderstorms/duststorms at Delhi

Wind direction at 900 m

	N	NNE	NE	ENE	E	ESE	SE	SSE	S
Total cases	34	25	12	10	18	58	35	45	29
No. of thunderstorms/duststorms	7	9	4	9	8	33	18	21	12
Frequency of occurrence (%)	21	36	33	90	44	57	51	47	41

	SSW	SW	WSW	W	WNW	NW	NNW	Calm
Total cases	43	31	37	109	377	234	106	0
No. of thunderstorm/duststorm	23	11	15	36	78	26	21	0
Frequency of occurrence (%)	54	36	41	33	21	11	20	0

of thermal wind between 700-500 m at Delhi and (*v*) Direction of wind at 900 m a.m.s.l. at Delhi.

Showalter (1953) developed a stability index to provide a simple and quick check on the possibility of occurrence of thunderstorms. Attempts to use

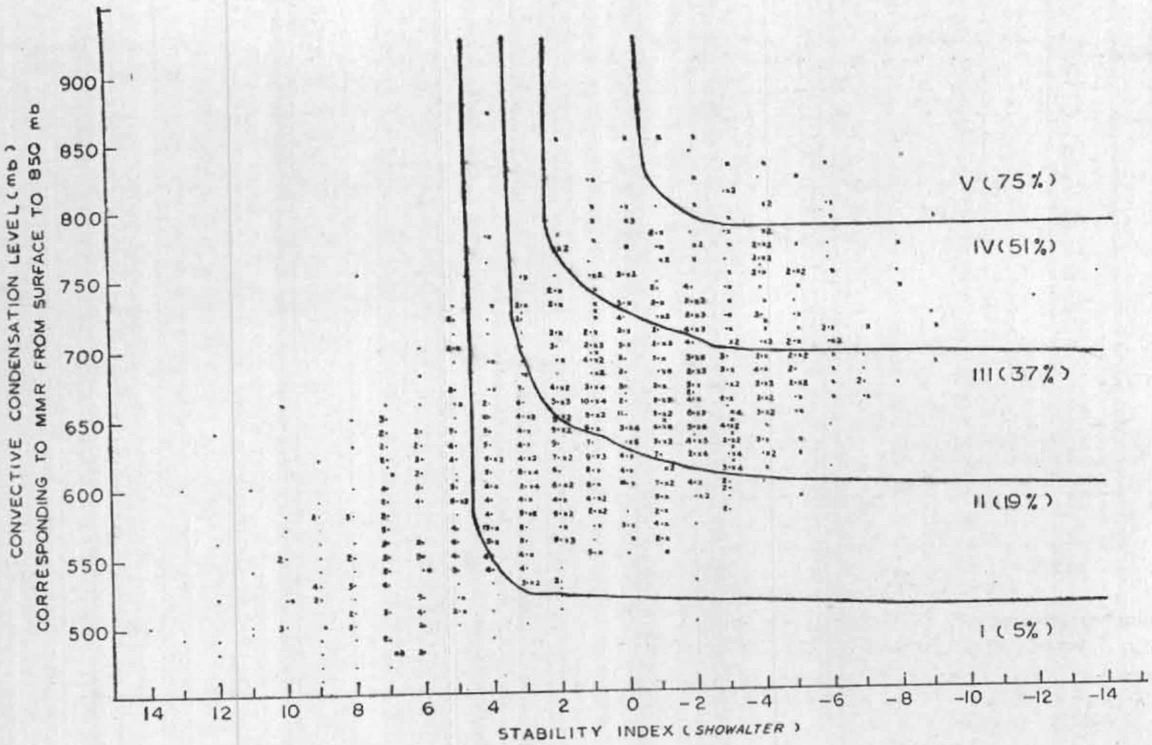

Fig. 1

Showalter's stability index for local forecasting of thunderstorms in India have been made by many investigators and their results indicate that it is a useful parameter.

The relationship of stability index as determined from 0530 and 1730 IST radiosonde data of Delhi to the subsequent thunderstorm/dust torm activities is shown in Table 1. It is obvious that the frequency of occurrence of convective activity increases with increase in instability.

The relationship of convective condensation level (CCL) corresponding to mean mixing ratio from surface to 850 mb at Delhi to the subsequent occurrence of thunderstorm/duststorm is shown in Table 2. This variable indicates fairly strong relationship to convective activity.

Legg (1948) and Tillotson (1951) found a useful relationship between the difference in 'height' of the convective condensation level and freezing level to thunderstorm activity in their studies for Denver (United States).

Table 3 shows the relationship of this variable to the subsequent thunderstorm/duststorm activity for Delhi.

The relationship of direction of thermal wind between 700-500 mb at Delhi to the subsequent convective activity is shown in Table 4.

Though the frequency to occurrence of thunderstorm/duststorm associated with the thermal wind from ESE, SE and SW is greater as compared to that with other directions of thermal wind, yet the parameter does not appear to have strong relationship with subsequent convective activity.

As the direction of wind at 900 m a.m.s.l. at Delhi may indicate if the moisture is being advected over the area this was taken up as one of the parameters for study. The relationship of wind direction at 900 m at Delhi to the subsequent occurrence of thunderstorm/duststorm activity is shown in Table 5.

(2) *Upper level moisture*

Mean of mixing ratio of 850, 800 and 700 mb at Delhi has been considered as a parameter representative of upper air moisture. However, moisture in the higher levels may also be significant for convective activity but we have to confine our study upto 700 mb only for the observations of moisture at higher levels are invariably absent, especially so, in the month of March and April. Table 6 shows the relationship of this parameter to the subsequent occurrence of thunderstorm/duststorm over Delhi and neighbourhood.

TABLE 6

Relationship of mean of mixing ratio at 850, 800 and 700 mb to the frequency of occurrence of thunderstorm/duststorm at Delhi

Class intervals of mean mixing ratio (gm/kg)	Total cases	No. of thunder-storm/dust-storm	Frequency of occurrence of thunder-storms/dust-storms (%)
0·0-3·5	253	17	7
3·6-7·0	591	159	27
7·1-10·5	217	94	43
>10·5	92	58	63

TABLE 7

Relationship of convergence and corresponding 24-hr change in convergence at 900 m to the frequency of occurrence of thunderstorms/duststorms at Delhi

Cate-gory	Convergence and 24-hr change in convergence	Total cases	No. of thunder-storm/dust-storm	Frequency of occurrence of thunder-storms/dust-storms (%)
I	HD and P	207	19	9
II	HD and N	89	12	13
III	D and P	250	56	22
IV	D and N	264	62	24
V	C and P	98	49	50
VI	C and N	254	141	55

HD—Highly Divergent ($\geq 5\cdot 00\times 10^{-5}$/sec), D—Divergent, C—Convergent, P—Positive changes, N—Negative changes

(3) *Lower level convergence*

As the lower level convergence is considered to be most favourable for large scale convective activity, attempt was made to investigate the relationship of convengence at 900 metres a.m.s.l. and corresponding 24-hr changes in convergence to the subsequent convective activity.

Bellamy's graphical method (1949) was used to compute the convergence values. The triangular area formed by the Pilot Balloon stations of Ambala, Jaipur and Bareilly was chosen for the purpose. Delhi lies at the centriod of the triangle.

In order to study the combined relationship of convergence and corresponding 24-hr change in convergence to the subsequent convective activity, six categories were defined. Table 7 shows these categories and corresponding frequency of thunderstorm/duststorm over Delhi and neighbourhood.

TABLE 8

Contigency tables of forecast *vs* observed thunderstorms/duststorms

		Forecasts		
		Thunder-storms/duststorms	Thunder-storms/duststorms	Total forecast
(a) *Forecasts made from developmental data March, April, May, and June 1964-68*				
Observed	Thunderstorms/Duststorms	187	150	337
	No. Thunderstorms/Duststorms	104	660	764
	Total	291	810	1101
Skill score : ·44		Percentage correct : 77%		
(b) *Forecasts made from test data, March, April, May and June 1969 and 1970*				
Observed	Thunderstorms/Duststorms	84	40	124
	No Thunderstorms/Duststorms	68	279	347
	Total	152	319	471
Skill score : ·45		Percentage correct : 78%		
(c) *Forecasts from developmental and test data combined*				
Observed	Thunderstorms/Duststorms	271	190	461
	No Thunderstorms/Duststorms	172	939	1111
	Total	443	1129	1572
Skill score: ·44		Percentage correct: 77%		

4. Combination of parameters

The following five variables showing strong relationship to the subsequent convective activity were finally selected—

(*i*) Stability Index (Showalter)

(*ii*) Convective condensation level corresponding to mean mixing ratio from surface to 850 mb.

(*iii*) Direction of wind at 900 m above m.s.l. at Delhi

(*iv*) Mean of mixing ratio at 850, 800 and 700 mb at Delhi and

(*v*) Convergence and corresponding 24-hr change in convergence at 900 m.

These five variables were combined graphically and related jointly to the frequency of occurrence of thunderstorms/duststorms over Delhi and neighbourhood as shown in Fig. 1 to 4. A cross in Fig. 1 and 2 represents a 'thunderstorm/duststorm'

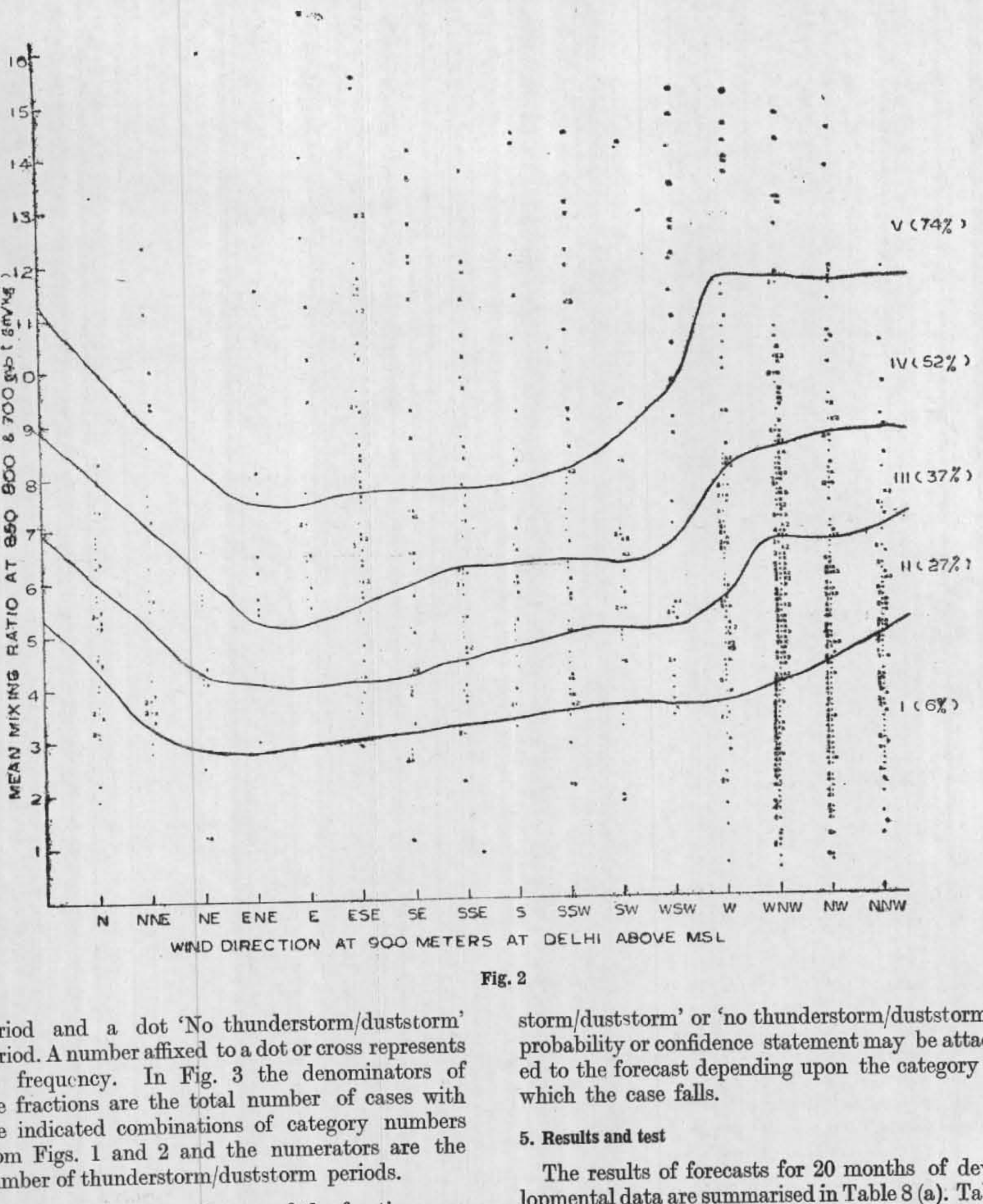

Fig. 2

period and a dot 'No thunderstorm/duststorm' period. A number affixed to a dot or cross represents its frequency. In Fig. 3 the denominators of the fractions are the total number of cases with the indicated combinations of category numbers from Figs. 1 and 2 and the numerators are the number of thunderstorm/duststorm periods.

In Fig. 4 the denominators of the fractions are the total number of cases with the indicated combination of category from Fig. 3 and Table 7 and the numerators are the number of thunderstorm/duststorm periods.

Fig. 4 is the final forecasting chart with thunderstorm/duststorm being forecast if the case falls above the solid line and no thunderstorm/duststorm being forecast if the case falls below the solid line. In addition to the categorical forecast of 'thunderstorm/duststorm' or 'no thunderstorm/duststorm' a probability or confidence statement may be attached to the forecast depending upon the category in which the case falls.

5. Results and test

The results of forecasts for 20 months of developmental data are summarised in Table 8 (a). Table 8 (b) is similar summary of forecasts made from the 8 months of test data. Table 8(c) summarizes the forecast for all the 28 months.

This method permits the forecaster to evaluate systematically several significant meteorological parameters and their combined effect on subsequent convective activity. Considerable skill can be obtained by the exclusive use of this method alone, but in certain cases it should be possible to

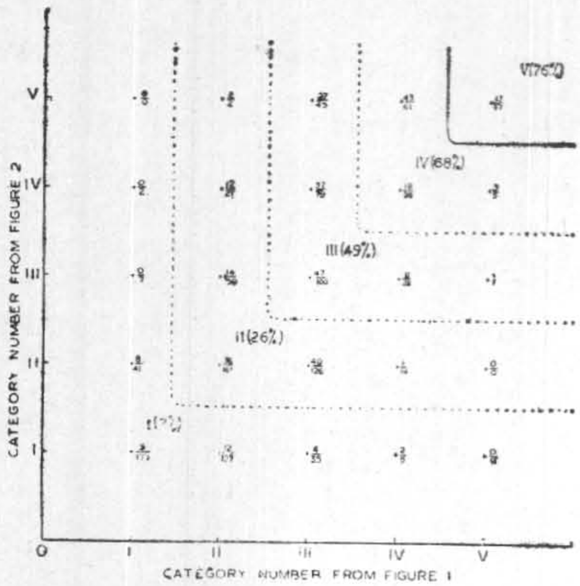

Fig. 3. Combination of categories from Figs. 1 and 2

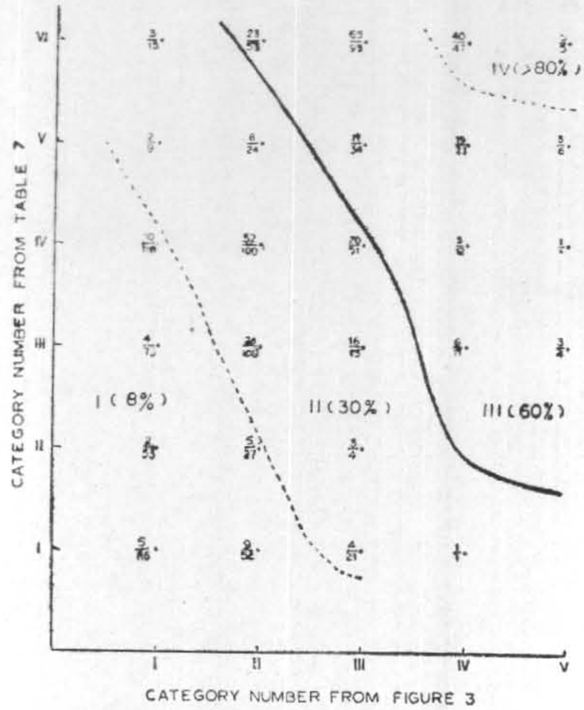

Fig. 4. Combination of categories from Fig. 3 and Table 4

The numerators of the fractions at each point indicate the number of thunderstorms/duststorms cases

make improvements by the subjective experience of the forecaster.

Since all factors contributing to convective activity over Delhi and neighbourhood have not been evaluated, better results are possible if unevaulated factors are kept in mind while issuing the forecasts.

6. Summary of method

For purpose of application, the following summary of the method may be useful.

(1) *Evaluate the following parameter*—(*a*) Stability index (Showalter), (*b*) Convective condensation level corresponding to mean of mixing ratio from surface to 850 mb graphically by equi-areal method, (*c*) Direction of wind in 16 points of compass at 900 m above m.s.l. at Delhi, (*d*) mean mixing ratio at 850, 800 and 700 mb in gm/kg and (*e*) Convergence and corresponding 24-hr change in convergence at 900 m.

(2) Enter the Fig. 1 with parameters (*a*) and(*b*) and determine the category number.

(3) Enter the Fig. 2 with parameters (*c*) and (*d*) and determine the category number.

(4) Enter the Fig. 3 with the category numbers from Figs. 1 and 2 and determine the category number.

(5 Enter Table 7 with the parameter (*e*) and determine the category number.

(6) Enter the Fig. 4 with the category numbers from Fig. 3 and Table 7. Forecast 'thunderstorm/duststorm' if the point falls above the solid line and 'no thunderstorm/duststorm' if below the solid lines.

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