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An objective method of forecasting thunderstorms in winter season over Delhi State

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ABSTRACT. The purpose of this study was to develop an objective aid for forecasting of thunderstorms in winter season over Delhi State. Relationship of a number of meteorological parameters to subsequent thunderstorm activity was investigated. The five parameters showing strongest relationship were finally selected and analysis applied to form objective forecast aid. The method was tested on independent data and the results were consistent with those obtained on developmental data.

1. Introduction

This study was initiated with a purpose of developing an objective aid for forecasting of thunderstorms in winter season over Delhi State. It was aimed at to set up objective procedures for 'yes' or 'no' thunderstorm forecast in the months of December, January and February during the periods 1130 to 2330 IST and 2330 to 1130 IST of the following morning, the forecasts to be based on 0530 IST and 1730 IST data respectively.

2. Selection of data

The developmental data for this study comprised five winter seasons 1963-64, 1964-65, 1965-66, 1966-67 and 1967-68. The data for two winter seasons 1968-69 and 1969-70 were reserved to test the procedure and termed as independent or test data.

A thunderstorm period was defined as — A thunderstorm recorded by observatories at Safdarjung and/Palam in New Delhi or a lightning squall recorded by these observatories.

In all 44 periods were designated as thunderstorm periods during the five winter seasons upon which the study was based.

3. Investigation of parameters

For the development of the forecasting aid many parameters were investigated and finally five were chosen in the same way as detailed in an earlier study by the author (1972).

The parameters are as follows —

(*i*) Stability Index (Showalter).

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

(*iii*) Difference between surface dew point and 500 mb temperature.

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

(*v*) Convergence at 900 metres at Delhi.

The parameters were tested for their usefulness by examining separately the relationship between each parameter and subsequent occurrence of thunderstorms over Delhi. The results of five parameters mentioned above which were found to be most suitable are given in Tables 1 to 5.

The triangular area formed by the Pilot Balloon stations of Ambala, Jaipur and Bareilly was chosen for the purpose. Delhi lies approximately at the centroid of the triangle.

Table 5 shows the relationship of convergence at 900 m to the subsequent occurrence of thunderstorms at Delhi. The class intervals of convergence were assigned by category numbers I to V. The convergence values were compiled by Bellamy's method (1949). This parameter also indicates fairly strong relationship to subsequent convective activity.

4. Combination of parameters

The five parameters discussed in the foregoing section were combined to form the objective aid for forecasting of thunderstorms over Delhi. The method applied in the present study is graphical discriminant analysis (WMO).

In Fig. 1 Stability Index (Showalter) was plotted against the directions of wind at 900 m above m.s.l. at Delhi. A 'cross' in the figure represents a 'thunderstorm period' and a 'dot' 'no thunderstorm period'. A number affixed to a dot or cross represents its frequency. The diagram was divided into two areas by fitting

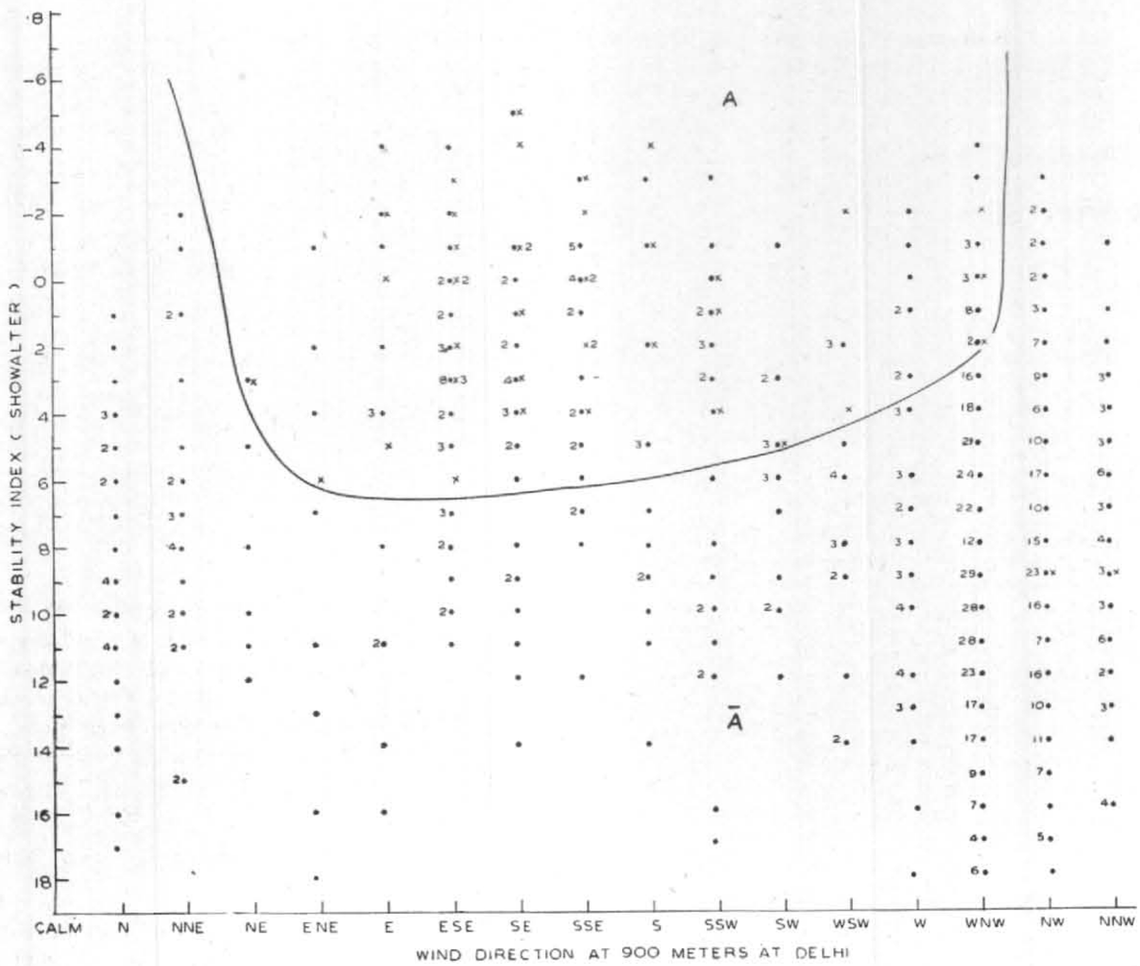

Fig. 1

TABLE 1

Relationship of Stability Index (Showalter) to the frequency of occurrence of thunderstorms

Stability Index	Total cases	No. of thunder-storms	Frequency of occurrence of thunderstorms (%)
>+4	625	6	1
+4 to +2	147	14	9
+1 to −1	75	14	19
⩽−2	26	10	38

TABLE 2

Relationship of difference between surface dew point and 500 mb temperature to the frequency of occurrence of thunderstorms

Class intervals of difference between surface dew point and 500 mb temp.	Total cases	No. of thunder-storms	Frequency of occurrence of thunderstorms (%)
<20	286	0	0
20—23	249	3	1
24—27	192	16	8
28—31	131	15	11
>31	37	11	30

TABLE 3

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

	Wind direction at 900 m																
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
Total cases	30	22	8	9	15	43	31	28	16	26	15	18	38	322	194	49	1
No. of thunderstorm cases	0	0	1	1	3	10	7	7	3	4	1	2	1	4	1	1	0
Frequency of occurrence of thunderstorms	0	0	12	11	20	23	22	25	19	15	7	11	3	1	<1	2	0

TABLE 4

Relationship of mean of mixing ratio at 850, 800 and 700 mb to the frequency of occurrence of thunderstorms

Class intervals of mean mixing ratio (gm/kg)	Total cases	No. of thunderstorm cases	Frequency of occurrence of thunderstorm (%)
$\leqslant 3\cdot0$	517	5	1
3·1—4·0	170	10	6
4·1—5·0	104	11	11
5·1—6·0	68	11	16
>6·0	20	8	40

TABLE 5

Relationship of convergence at 900 m to the frequency of occurrence of thunderstorms at Delhi

Category number	Class intervals of convergence (10^{-5}/sec.)	Total cases	Number of thunderstorm cases	Frequency of occurrence of thunderstorms (%)
I	$\leqslant 2\cdot00$	458	8	2
II	1·99 to 0·01	189	2	1
III	0·00 to —1·99	111	7	6
IV	—2·00 to —3·99	48	7	14
V	>—4·00	51	22	43

subjectively a curve so that most of the crosses were included in area A and most of the dots in area $\bar{A}$.

The cases in area A were plotted in Fig. 2 with coordinates as difference between surface dew point and 500 mb termperature and mean of mixing ratio at 850, 800 and 700 mb at Delhi. The further separation of crosses from dots was obtained by fitting a curve and dividing Fig. 2 into two areas B and $\bar{B}$. In the area B most of the crosses are contained and in area $\bar{B}$, an overwhelming number of dots are to be found.

The cases contained in area B were then plotted in Fig. 3 with category number from Table 5 and mean of mixing ratio at 850, 800 and 700 mb as coordinates. The best separation of crosses and dots was obtained by drawing a curve so as to divide Fig. 3 into two areas C and $\bar{C}$. In the area C the crosses predominate and in area $\bar{C}$ most of the dots are to be found.

To use this objective aid in practical forecasting we enter Fig. 1 with parameters (*i*) and (*ii*). If the point falls in area $\bar{A}$ forecast 'No thunderstorm' and stop. If the point falls in area A, we enter the Fig. 2 with parameters (*iii*) and (*iv*). If the point falls in area $\bar{B}$ we forecast 'No thunderstorm'. On the other hand if the point falls in the area B, we proceed to Fig. 3 with the parameters (*iv*) and (*v*).

If the point falls in area $\bar{C}$ 'No thunderstorm' is the forecast and 'Thunderstorm' is the forecast if it falls in area C.

5. Results and test

The results of applying the objective forecast aid to five winter seasons of developmental data are summarized in Table 6(a). Table 6(b)

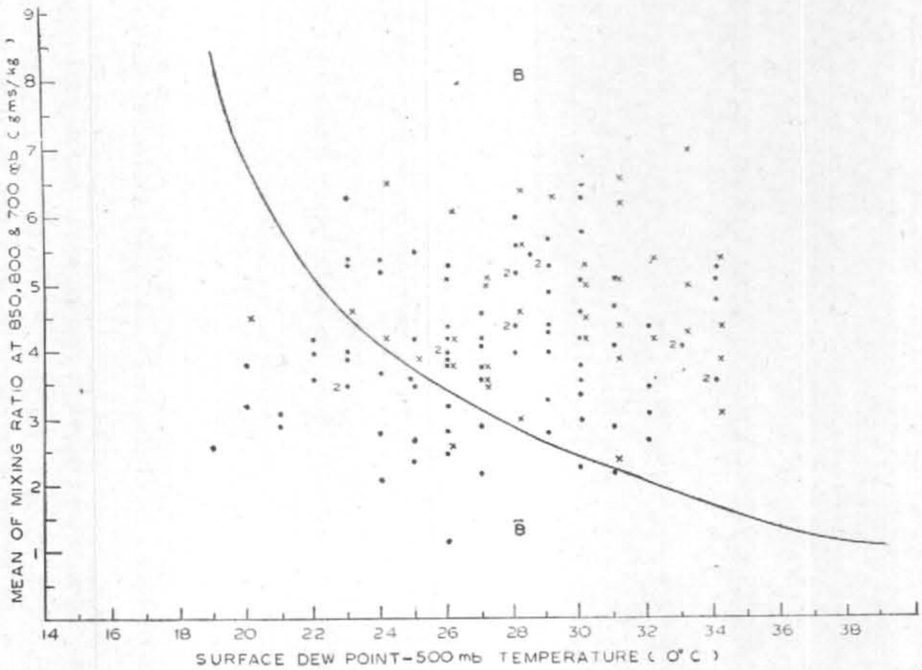

Fig. 2

TABLE 6 (a)

Forecasts made from developmental data comprising five winter seasons (1963-1968)

		Forecasts		
		Thunder-storms	No thunder-storms	Total
Observed	Thunderstorms	30	14	44
	No thunderstorms	27	802	829
	Total	57	816	873
	Per cent correct :	95	Skill score : ·57	

TABLE 6 (b)

Forecasts made from test data comprising two winter seasons 1968-69 and 1969-70

		Forecast		
		Thunder-storm	No thunder-storms	Total
Observed	Thunderstorms	10	9	19
	No thunderstorms	9	331	340
	Total	19	340	359
	Per cent correct : 95		Skill score : ·50	

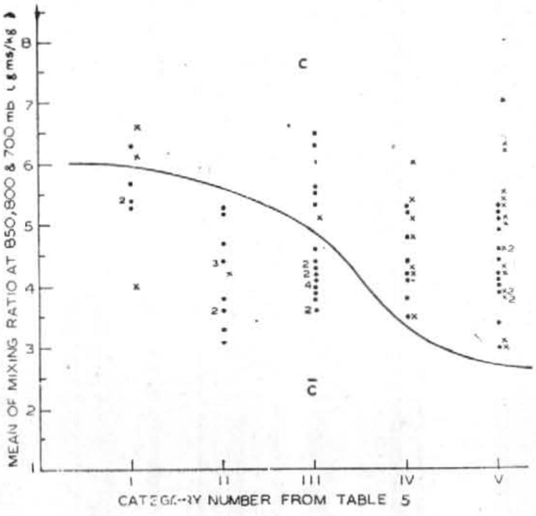

Fig.3

is a similar summary of forecasts made from two winter seasons of test data. The skill score is based on the marginal totals of the contigency table.

It is seen from Table 6 that the objective procedure gives an overall percentage of correct forecast as 95 but in the case of 'yes' thunderstorm forecast percentage correct is 53 only both for developmental and test data. Since all the factors contributing to thunderstorm activity over Delhi State have not been evaluated, the limitations of this forecasting aid must be kept in view. However, it would be useful objective aid for forecasting of winter thunderstorms over Delhi.

6. Summary of method

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

(1) Determine the parameters — (*i*) Stability Index (Showalter) and (*ii*) Direction of wind in 16 points of compass at 900 m above m.s.l. at Delhi.

(2) Plot values of the parameters (*i*) and (*ii*) in Fig. 1.

(3) If the case falls in area $\bar{A}$ of Fig. 1, forecast 'No thunderstorm' and stop.

(4) If the case falls in area A determine the parameters — (*iii*) Difference between surface dew point and 500 mb temperature and (*iv*) Mean of mixing ratio at 850, 800 and 700 mb in gm/kg.

(5) Plot values of the parameters (*ii*) and (*iv*) in Fig. 2.

(6) If the case falls in area $\bar{B}$ forecast 'No thunderstorm' and stop.

(7) If the case falls in B, evaluate convergence at 900 m and determine the category number from Table 5.

(8) Plot the above category number and value of the parameter (*iv*) in Fig. 3.

(9) If the case now falls in area $\bar{C}$ of Fig. 3 forecast 'No thunderstorm' and if it falls in area C forecast 'Thunderstorm'.

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