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Stability Index and Thunderstorms over Nagpur

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ABSTRACT. In this study, dependence of thunderstorm occurrences on stability index and the mean mixing ratio in the 850 to 700-mb layer has been examined. It is seen that most of the thunderstorms occur when the mean mixing ratio lies between 4·5 and 9·0 g/kg in March and April increasing to 6·5 to 13·0 g/kg in May and June. No thunderstorms occur when the mean mixing ratio of 850 and 700-mb layer is less than 3·5 g/kg.

Further, the difference of mixing ratios between 850 and 700-mb layers, which gives an idea of stability or instability in the 850 to 700-mb layer, was also examined for its influence on the thunderstorm formation and growth in a certain height group. The comparison of these heights with radar echo heights show a convincing proximity.

1. Introduction

A method of quick check on thunderstorm possibilities was developed by Showalter (1953), namely, that the 850-mb parcel (mountain area stations use a higher level) is lifted dry adiabatically to saturation and then pseudo-adiabatically to 500-mb temperatures. The lifted 500-mb temperatures is then subtracted algebraically from the observed 500-mb temperature. A negative number shows instability (rising air warmer than its surroundings) and a positive number indicates stability. Basu (1962), Tripathi (1956) and Joseph (1957) have investigated the application of this method over Delhi, Poona and Madras respectively and Seshadri (1962) took into account the humidity as well.

2. Study

In this paper, the success of Showalter's stability index method for Nagpur has been investigated in the first instance. The tephigrams of 00 and 12 GMT radiosonde ascents for the months of March to June and for the years 1958 to 1962 have been analysed for 850-mb and 500-mb levels.

In the second step, the stability index and the corresponding mean of the mixing ratio at 850 and 700 mb have been examined and in the third step, the influence of the difference in mixing ratio of 850-mb and 700-mb levels on the storm formation and its growth with reference to stability index was examined and compared with radar observations.

In all 1134 ascents (00 GMT and 12 GMT) were analysed. Out of these, data for stability index on 1054 occasions and both for S.I. and m.m.r. (mean mixing ratio) on 1020 occasions were available. The study was kept restricted to those cases where instability phenomenon was either not occurring at the time of the observation or there was a lag of more than 2 hours between the occurrence of phenomenon and the time of ascent.

3. Results

3.1. It is noticed that during the 12-hour period after the time of routine soundings, instability phenomena occurred on 50 occasions out of 105 with S.I. being <-4, *i.e.*, on 48 per cent of the cases. Similarly the percentage occurrence is 44, 37 and 25 for the indices between <-2 to $\geqslant -4$, 0 to $\geqslant -2$ and 0·0 respectively, indicating a progressive decrease of thunderstorm activity, as value of stability index increased, being only 3 per cent when the S.I. is $> +4$.

3.2. Table 1 gives the distribution of the instability phenomena with respect to mean mixing ratio. It is observed that in the region of mean mixing ratio (m.m.r.) $\geqslant 7$ g/kg, the percentage of thunderstorm occurrence is 47·6, 43·7, 23·7 for S.I. <-4, $\geqslant -4$ to <0, $\geqslant 0$ to $\leqslant +4$ respectively.

For values of m.m.r. between 3·5 to 7 g/kg the percentage of thunderstorm occurrences stands as 21·7, 23·8 and 10·3 for S.I. <-4, $\geqslant -4$ to <0, $\geqslant 0$ to $\leqslant +4$ respectively.

Finally when m.m.r. values lie between 0—3·5 g/kg, there is no thunderstorm activity irrespective of S.I.

Also when the S.I. is $> +4$, thunderstorm activity is *nil* except for few exceptional cases (2·0 per cent) in the region of 3·5 — 7 g/kg of m.m.r.

3.3. Most of the thunderstorms occur when stability index lies between +4 and —8 and mean mixing ratio between 4·5 and 9·0 in March and April, increasing to 6·5 to 13·0 g/kg during May to June.

3.4. Difference in mixing ratio (d.m.r.) between 850 and 700-mb levels, which to some extent gives an idea of instability or stability in that layer for positive or negative value, was further plotted against the number of occurrences of thunderstorms for each of the stability index group <0 to -4, <-4 to -8 and >0 to $+8$, from March to June, in Figs. 1(a) to 1(d), in order to examine the dependence of the thunderstorm formation and growth on d.m.r. in the layer 850 to 700 mb.

Weak thunderstorms have been chosen to have the height of the tops ranging up to 6 km, moderate

TABLE 1

S. I.	−4 to −8			0 to −4			0 to +4			+4 to +8		
m.m.r. (g/kg)	7 or more	3·50–7	0–3·5	7 or more	3·5–7	0–3·5	7 or more	3·5–7	0–3·5	7 or more	3·5–7	0–3·5
					MARCH (1958—1962)							
No. of occasions	5	2	Nil	21	30	1	2	96	4	Nil	62	47
No. of occurrences	4	1	Nil	7	8	Nil	Nil	9	Nil	Nil	2	Nil
Percentage	80	50	—	33	27	—	—	10	—	—	3	—
					APRIL (1958—1962)							
No. of occasions	13	7	Nil	34	45	Nil	18	98	Nil	Nil	28	4
No. of occurrences	8	Nil	Nil	14	12	Nil	5	10	Nil	Nil	1	Nil
Percentage	57	—	—	42	26	—	28	10	—	—	4	—
					MAY (1958—1962)							
No. of occasions	18	4	Nil	77	35	1	42	68	2	2	21	2
No. of occurrences	7	2	Nil	33	7	Nil	4	7	Nil	Nil	Nil	Nil
Percentage	39	50	—	43	20	—	9	10	—	—	—	—
					JUNE (1958—1962)							
No. of occasions	38	1	Nil	113	7	Nil	56	11	Nil	5	1	Nil
No. of occurrences	16	Nil	Nil	61	1	Nil	19	2	Nil	Nil	Nil	Nil
Percentage	42	—	—	55	14	—	30	18	—	—	—	—
Mean percentage	47·6	21·7	—	43·7	23·8	—	23·7	10·3	—	—	2	—

TABLE 2

Height of top of thunderstorm corresponding to S. Index and most probable range of d.m.r. (difference in mixing ratio between 850 and 700-mb levels) from March to June

	Stability Index	d.m.r. values corresponding to height of the top of the thunderstorm			
		upto 6 km Weak	> 6 to 9 km Moderate	>9 to 12 km Strong	> 12 km Very strong
March	0 to −4	0 to −2	1 to 2	3 to 4	—
	−4 to −8	0 to +1	0 to 1	—	3 to 4
	0 to +8	1 to −1	2 to 3	—	—
April	0 to −4	0 to −1	1 to 2	from 3 onwards	—
	−4 to −8	0 to 1	more than 1	—	—
	0 to +8	1 to 2	—	—	—
May	0 to −4	0 to −1	1 to 3	from 3 onwards	—
	−4 to −8	0 to 1	more than 1	—	—
	0 to +8	0 to 1	—	—	—
June	0 to −4	1 to −1	1 to 1 2 to 3	5 to 6	—
	−4 to −8	—	—	3 to 4	6 to 8
	0 to +8	1 to 2	4 to 5	—	—

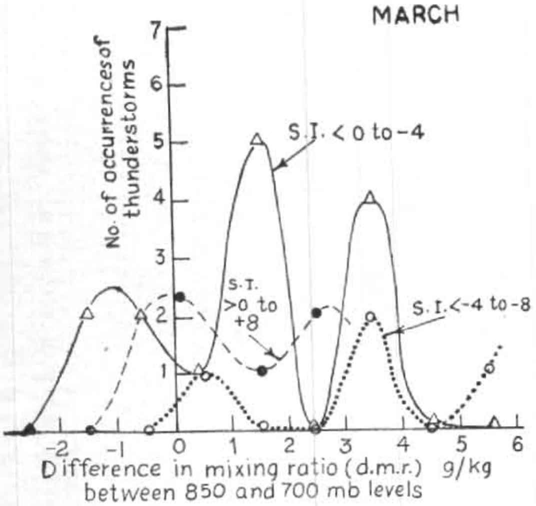

Fig. 1(a)

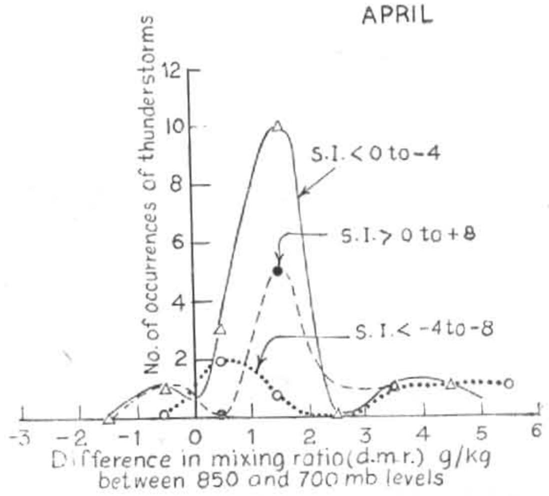

Fig. 1(b)

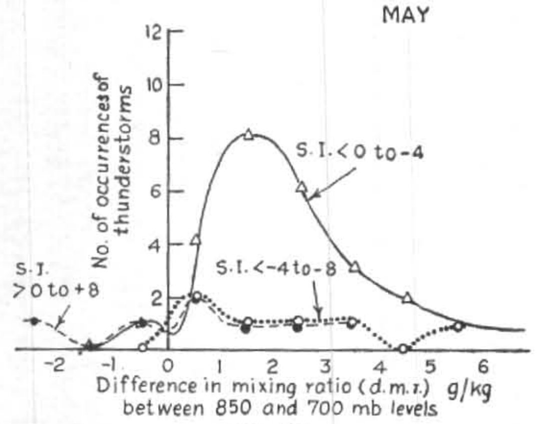

Fig. 1(c)

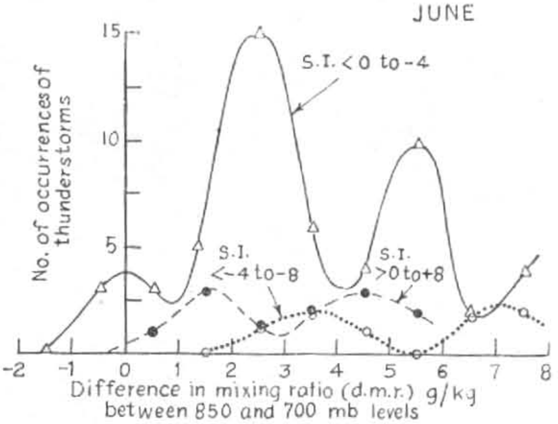

Fig. 1(d)

ones to have heights of the tops >6 km to ⩽9 km, while strong and very strong thunderstorms from >9 km to ⩽12 km and > 12 km respectively. The results, given in Figs. 1(a) to 1(d), have been summarised in Table 2, which shows the height of the top of the thunderstorms corresponding to different groups of stability indices and the most probable range of d.m.r. for the months of March to June.

4. Corroboration by reference to radar observations

The categorisation of thunderstorms in terms of height groups of ⩽6 km, >6 to ⩽9 km, > 9 to ⩽12 km and >12 km, has been tested by radar echo tops available from March to June for the year 1964. The testing of the strength of the thunderstorms with squall speed experienced at the station has not been attempted, since some thunderstorms may lie at a distance from the station and give a squall which reaches the station with poor strength. Thus the records at the station which are poor, may lead to overestimation of the top of the thunderstorm. The radar heights and those expected from the study gave a close proximity between the two.

5. Remarks

5.1. An interesting fact is manifested from Figs. 1(a) to 1(d). It may be noticed that in each month and practically in every group of stability index, there are one or two maxima of actual thunderstorm occurrences. As is already known that thunderstorm development depends upon synchronisation of favourable conditions in the layers below and aloft 850 – 700 mb layer also, d.m.r. values for layers ground-850 mb were also simultaneously studied, in arriving at a possible explanation for these maxima.

5.2. After comparing the expected thunderstorm tops with those of radar echo tops around Nagpur, it has been seen that, even though all the conditions were favourable for categorising a thunderstorm in one height of the top group, the negative difference of mixing ratio between ground and 850-mb level had inhibited most of the thunderstorm development during the months March to May. However, the negative values of difference in mixing ratio between ground and 850-mb level in the months of April and May were less effective in preventing the thunderstorm formation when the mean mixing ratio (m.m.r.) is high, the d.m.r. in 850-700 mb layer is favourable and these are associated with highly negative stability index; under such conditions weak thunderstorms detectable by radar would form. Negative values of difference in mixing ratio between ground and 850 mb were, however, less inhibitory in the month of June; thunderstorms occur even with a negative d.m.r. from ground to 850 mb in the month of June. Probably the moisture incursion takes place, after the time of ascent, at any time during the day in this month and thus making the conditions from unfavourable to favourable for the occurrence of a thunderstorm. It has been seen in a few cases in 1964 that in the month of June, when all other conditions are favourable no thunderstorm had occurred because lifting condensation level was very high (near about 700 mb).

5.3. If d.m.r. in 850 to 700-mb layer is negative and that in ground to 850-mb level is positive, then the storm's growth reached the next higher category of top groups than the one in which it lies according to d.m.r. in 850-700mb layer. Thus a weak storm may become weak to moderate, when there is a positive d.m.r. in ground to 850-mb level, but negative d.m.r. in 850 to 700-mb layer.

5.4. When d.m.r. is zero or negative in 850 to 700-mb layer, the thunderstorm which occurs is a delayed and short lived. Also if d.m.r. continues to be zero or negative, after thunderstorm has occurred or occurring by the next radiosonde ascent time, it will tend to dissipate in short or long time depending upon the negativity of the d.m.r. Highly negative d.m.r. will tend to dissipate the thunderstorm very quickly.

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