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Radar study of line type echoes as observed at Agartala aerodrome, Tripura during February-October 1964

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ABSTRACT. Occurrences of line type echoes over Agartala aerodrome and its neighbourhood during February-October 1964 have been studied with respect to their shapes, dimensions, orientations, movements, times of occurrences, life cycles and the associated synoptic situations. It has been found that the lines have marked preferences for their formations in different sectors in different seasons. The movements of the lines are found to be associated with upper winds at 3-km level in the monsoon season. Instances of formations of secondary cells in the forward, backward and lateral sectors of the main squall lines have also been observed. An explanation for the formation of these secondary cells has been offered.

1. Introduction

With the existing chain of widely scattered observatories it is likely that many thunderstorm phenomena may go undetected. In fact, there have been occasions when formation of squall lines could not be confirmed due to paucity of a high density of observatories. On such occasions radar observations prove to be of immense use to the meteorologist. The radar can keep a continuous watch over a wide area and monitor whether the thunderstorms occurring over the area have originated from isolated thunderstorm cells or squall lines.

Over Agartala aerodrome and its neighbourhood thunderstorms are generally absent during December to February. They occur quite frequently during the rest of the year. Out of these, the number of occasions when they occur as squall lines is quite appreciable. During the period February-October 1964, there were 123 days when 183 squall lines (solid or broken) were detected by the medium powered Bendix radar* installed at Agartala aerodrome. Out of these, 119 squall lines passed over the aerodrome.

The movements of these squall lines are generally correlated to the upper winds but there are occasions when these line echoes have been found to move against the direction of upper winds (De 1963). An attempt has been made in this study to find out if any correlation exists between the movement of squall lines and the upper winds.

2. Location of Agartala aerodrome

Agartala aerodrome is situated in the easternmost part of the country in the Megna valley and at the feet of Baramura, Atharamura and Lungthrai ranges. These hills are located at the eastern side of the station and extend in the N-S direction. They slope upwards as the distance from the station increases. To the north lies the Garo-Khasia-Jaintia ranges at a distance of about 80 n. miles.

3. Data

The season-wise frequency distribution of the line type echoes reported in this study is given in Table 1.

As the number of occasions when the line type echoes were detected on the radarscope during the winter season was only 4, the same has not been included in this study.

4. Analysis of the data and discussion

4.1. *Nature of the line formations* — On examination of the radarscope presentations, it has been observed that on some occasions the cells comprising the line type echoes were wide apart and the individual cells could clearly be identified on the scope due to the wide gap in between them. These lines have been termed broken lines. But on some occasions the cells were so close to one another that they were no longer identifiable on the radarscope. These lines have been termed solid lines.

In the present case for the Bendix WTR-1 radar in use at the station, the limit of resolution at 50 n. miles is about 2·5 n. miles. This means that if the gap between the near edges of two thunderstorm cells comprising a line at a distance of 50 n. miles from the station is less than 2·5 n. miles, the two cells would appear as one on the radarscope. On the other hand, if the separating distances are more than the limiting value, they would appear as two different echoes giving a "broken" appearance to the line type echoes. Table 2 shows the details of the solid and broken lines as they appeared on the radarscope during different seasons of 1964.

*Specifications — type : WTR-1, peak power : 20 KW, wave length 3·2 cm, pulse duration : 2·5 μ sec, p.r.f. : 400 per sec, beam width : 2·9 deg., scope : PPI, maximum range : 150 n. miles, range of elevation angles :—5 to +15 deg.

TABLE 1

Frequency of line type echoes

Season	No. of lines observed on the radarscope	No. of lines which hit the acrodrome
Winter	4	2
Pre-monsoon	29	18
Monsoon	124	78
Post monsoon	26	21
Total	183	119

TABLE 2

Number of broken and solid lines in different seasons

Season	Broken line	Solid line		Total
		Partly	Mainly	
Pre-monsoon	16	3	10	29
Monsoon	73	23	28	124
Post monsoon	13	5	8	26
Total	102	31	46	179

4·2. *Length of the line type echoes*—The frequency distribution of the line-type echoes are tabulated in Table 3.

It is seen from Table 3 that during the year under study, about 50 per cent of the lines were more than 50 n. miles in length. In the pre-monsoon and post monsoon seasons, about 70 per cent of the lines were more than 50 n. miles, the percentage figure during the monsoon season being only 41.

4·3. *Width of the line type echoes* — The width of the line type echoes were measured when they were within 10-15 n. miles from the station. Their seasonwise distribution is shown in Table 4.

It may be seen from Table 4 that the average width of the lines was about 8 n. miles. The above figure has certain limitations due to low-power and large beam width of the radar.

4·4. *Orientation of the lines* — In order to see if there was any preference as to the orientations of the line formations, the orientation has been taken as X° in the orientation when the lines were in the direction X° to (X+180)°. The frequency distribution of orientations of the line type echoes has been tabulated and the result shown in Table 5. A few line type echoes of different orientations are illustrated in Fig. 1.

It is seen from Table 5 that the line type echoes appear to have a marked preference for the orientation 181-210° and 331-360° in the monsoon, 241-270° in the pre-monsoon and 211-240° in the post monsoon seasons. Thus 211-240° is the most preferred orientation during the monsoon and post monsoon seasons.

4·5. *Movement of the line type echoes* — The frequency of direction to which the line type echoes of different orientations (within the radar range) were found to move is shown in Table 6 (a). The average speed of movement is indicated in Table 6 (b).

It is seen from Table 6(a) that in the pre-monsoon season, most of the lines came from N and W directions. In the monsoon season in addition to lines moving from W to E, a good number of the line type echoes moved from S to N.

It is seen from Table 6(b) that the maximum frequency occurred in the group 8-12 kts in all the seasons. The average speed of line type echoes during the pre-monsoon season is 14 kts, the average speed during the other two seasons being smaller.

4·6. *Movement of the line type echoes vis-a-vis actual upper winds* — Next, an attempt was made to see if any correlation exists between the echo movement with the actual winds of respective dates. It has been found that the correlation between the movement of the line type echoes and wind velocities in the layers 1·5–4·5 km was quite high. Agartala aerodrome is a Pilot Balloon station. As such, upper winds in respect of Agartala and neighbourhood are available only from pilot balloon ascents. But unfortunately the extent of flights was limited on many occasions. However, 139 out of 179 (Table 1) occasions could be studied with reference to the actual upper winds. The results are shown in Table 7 and Fig. 2. It is seen from Fig. 2 (d) that the echo movements were closely associated with the winds at 3·3 km. In general, the average direction (in wind direction sense) of echo movements was found to veer with respect to the actual winds at all the levels, while the average speeds of echo movements were found to be less than the velocities of the winds at the corresponding levels. It has also been found that in the post monsoon season, the lines moved in the direction similar to that of winds at 3·0 to 3·6-km levels. In the monsoon season their correlation was particularly high with the winds at 3·0 km. In the pre-monsoon season the correlation was less prominent than that during the other two seasons. But, the movement was somewhat similar to the winds at 3·6 km.

4·7. *Life time of the lines* — Due to paucity of the data, the life time of the lines could not be

TABLE 3

Frequency distribution of lengths of line type echoes

Length of line type echoes (n. miles)	Pre-monsoon	Monsoon	Post monsoon	Total
10— 20	..	2 (2)	..	2 (1)
21— 30	2 (7)	14 (11)	..	16 (9)
31— 40	2 (7)	26 (20)	4 (15)	32 (18)
41— 50	5 (17)	31 (25)	4 (15)	40 (23)
51— 60	5 (17)	25 (20)	7 (27)	37 (21)
61— 70	3 (10)	14 (11)	5 (19)	22 (12)
71— 80	4 (14)	7 (6)	5 (19)	16 (8)
81— 90	1 (4)	1 (1)	..	2 (1)
91—100	1 (4)	2 (2)	..	3 (2)
>100	6 (20)	2 (2)	1 (4)	9 (5)
Total	29	124	26	179

Figures within brackets indicate percentage

TABLE 5

Frequency distribution of orientations of the line type echoes

Orientation (deg.)	Pre-monsoon	Monsoon	Post monsoon	Total
181—210	5	29	5	39
211—240	4	24	10	38
241—270	11	23	1	35
271—300	6	12	4	22
301—330	2	15	5	22
331—360	1	21	1	23
Total	29	124	26	179

TABLE 4

Frequency distribution of width of line type echoes

Season	Width of the line type echoes (n. miles)					Total
	2—4	5—7	8—10	11—13	14—16	
Pre-monsoon	1 (3)	9 (31)	16 (55)	1 (3)	2 (7)	29
Monsoon	18 (15)	50 (40)	43 (35)	6 (5)	7 (6)	124
Post monsoon	4 (15)	7 (27)	8 (31)	3 (11)	4 (15)	26
Total	23 (12)	66 (37)	67 (37)	10 (6)	13 (7)	179

Figures within brackets indicate percentage

TABLE 6 (a)

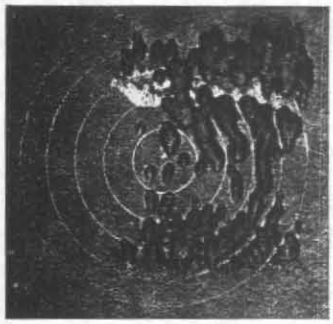
Frequency distribution of the directions to which the line type echoes are moving

	N	NE	E	SE	S	SW	W	NW	Station-ary	Total
Pre-monsoon	2	3	10	3	9	1	1	..	..	29
Monsoon	18	14	44	8	9	3	8	19	1	124
Post monsoon	14	2	6	1	1	..	2	..	..	26
Total	34	19	60	12	19	4	11	19	1	179

TABLE 6 (b)

Frequency distribution of average speed (kts) of movement of line type echoes

	< 3	3—7	8—12	13—17	18—22	23—27	28—30	Total	Average
Pre-monsoon	..	3	10	6	7	3	..	29	14
Monsoon	1	38	58	17	8	1	1	124	10
Post monsoon	..	11	13	2	..	..	..	26	8
Total	1	52	81	25	15	4	1	179	11



1720 270–300° 10

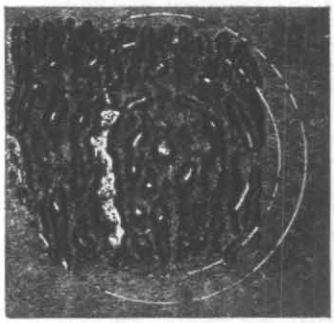
(a)—1 April 1964

0145 240–270° 10

(b)—3 April 1964

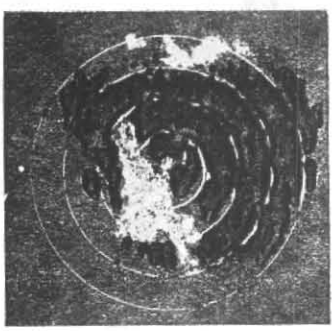
2100 180–210° 10

(c)—6 October 1964



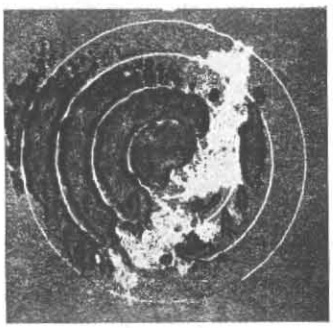
1645 180–210° 10

(d)—2 September 1964



1508 300–330° 5

(e)—30 July 1964



2106 210–240° 5

(f)—3 September 1964

Figs. 1(a—f). PPI presentation of the storm warning radar at Agartala aerodrome on different dates showing different orientations ofthe linetype echoes

Figures below the photographs indicate (from left): Time in IST, azimuth in degrees and range rings (n. miles)

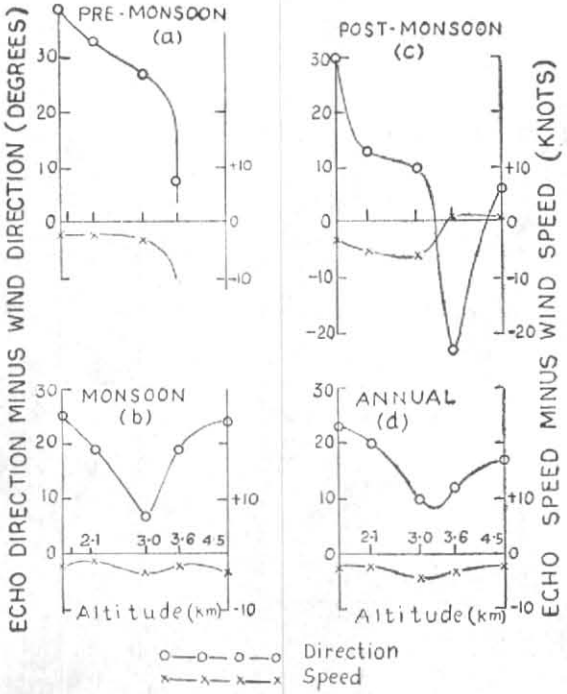


Fig. 2. Mean difference between the directions and speeds of echo and wind at different heights

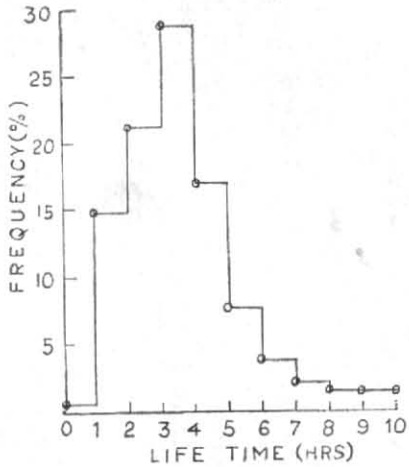


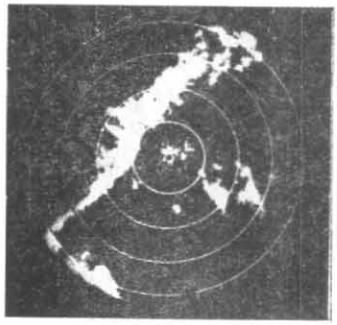
Fig. 3. Life time of the line echoes *vs* frequency (%)

determined with a greater degree of accuracy. However, the frequency of duration of the available data has been shown in Fig. 3. Out of 183 lines available for the study, 26 (15 per cent) lasted for 2 hours, 39 (21 per cent) for 3 hours, 53 (29 per cent) for 4 hours, 31 (17 per cent) for 5 hours, 14 (8 per cent) for 6 hours and the remaining 18 (10 per cent) for 7 to 12 hours. It is seen that the frequency was maximum (29 per cent) for 3–4 hours duration of the lines. This agrees with the findings of De (1963) for a similar study at Dum Dum airport (Calcutta).

4.8. *Preferred time of formations of the line type echoes* — To find if there is any preference for the time of formation of these lines, the day was divided into five periods comprising of morning (0531-0830 IST), noon (0831-1230 IST), afternoon (1231-1730 IST), evening (1731-2030 IST) and night (2030-0530 IST). The relevant data are shown in Table 8. It is seen from the table that the largest number of lines occurred during afternoon in all the seasons.

4.9. *Heights of the tops* — The frequency of the number of occasions when the line type echoes reached different height values are shown in Table 9. It will be seen from the table that the development of maximum height varies from season to season. The number of occasions when the echoes reached more than 12·3 km was maximum during the pre-monsoon and minimum during the post-monsoon season. In the pre-monsoon season 60 per cent of the line type echoes attained the height of more than 9·3 km. In the monsoon and post monsoon seasons, their percentages came down to 10 and 19 respectively.

4.10. *Secondary formations* — It is seen that on most of the occasions some secondary cells developed near the original squall lines. Their formation with respect to the main lines have been studied. A few examples are shown in Fig. 4. Out of 161 occasions when the secondary growth was observed, the distribution was as follows: 119 occasions in the front, 61 behind, 18 to the right and 18 to the left of the lines. Here the front indicates the direction to which the line was moving. Sometimes cells were noticed simultaneously in two or three directions. Hence the number of occasions of secondary cell formations have exceeded the actual number of lines studied. Whereas the cells to the front could be detected, the detection of cells at the back might be limited due to the attenuation of the radar beam while travelling through the main squall line. Similarly, if the length of the line is appreciably large, the cells to the right and left might also escape detection due to range attenuation. Byers and Braham (1949) found a large number of secondary cell formations on the right lateral sectors. Raghavan (1962) also found a preference for secondary formations on the right sector.



2106 29-7-64 5

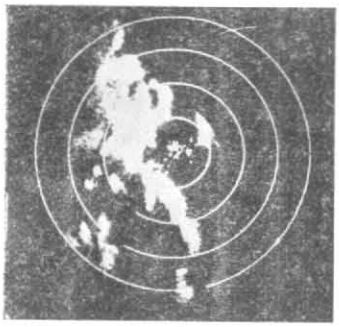
Fig. 4(a). Cells in front

0023 7-10-64 5

Fig. 4(b). Cells in front

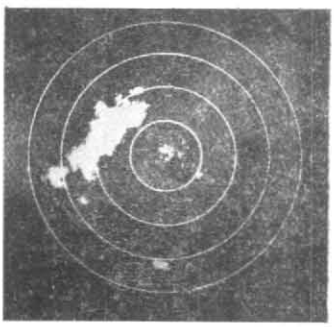
2012 3-9-64 5

Fig. 4(c). Cells to the left and right



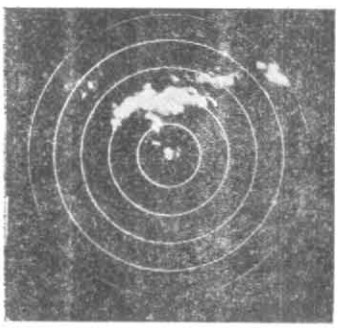
1620 15-7-64 5

Fig. 4(d). Cells to the back and front



1546 21-5-64 5

Fig. 4(e). Cells to the right and front



0125 3-5-64 10

Fig. 4(f). Cells to the back and left

Figs. 4(a—f). PPI presentation of storm warning radar at Agartala aerodrome on different dates showing secondary cell formations in association with the line type echoes

Figures below the photographs indicate (from left) : Time in IST, date and range rings in n. miles

TABLE 7

Mean difference between echo movement and wind direction and speed at different altitudes

	1·5 km			2·1 km			3·0 km			3·6 km			4·5 km		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Pre-monsoon	+39	—2	27	+33	—2	19	+27	—3	12	+ 8	—11	3	—	—	—
Monsoon	+25	—2	93	+19	—1	80	+ 7	—3	54	+19	—2	33	+24	—3	17
Post monsoon	+30	—3	19	+13	—5	19	+10	—6	17	—23	+1	6	+ 6	+1	5
Average for the year	+23	—2	139	+20	—2	118	+10	—4	83	+12	—3	42	+17	—2	22

(a) Direction in degrees, (b) Speed in knots, (c) No. of cases

TABLE 8

Frequency of line type echoes during different periods of the day

Season	Morning (0531-0830)	Noon (0831-1230)	Afternoon (1231-1730)	Evening (1731-2030)	Night (2031-0530)	Total
Pre-monsoon	1	5	11	3	9	29
Monsoon	11	24	42	10	37	124
Post monsoon	2	4	11	2	7	26
Total	14	33	64	15	53	179

TABLE 9

Frequency of the heights of tops of line type echoes in different seasons

Season	Height (km)					Total
	3·0-5·4	5·5-7·0	7·1-9·2	9·2-12·3	>12·3	
Pre-monsoon	1	5	5	9	9	29
Monsoon	30	40	41	11	2	124
Post monsoon	4	10	7	5	—	26
Total	35	55	53	25	11	179

But secondary formations in the front appear to have some preference over other sectors at Agartala.

The secondary formations in the front showed that in the area ahead of the line, convection was sometimes concentrated within a zone rather than along a single line. Moreover, it is well known that a large amount of down flow of air in the downdrafts of the thunderstorms while spreading outwards through the warm moist air, causes more convection and new cells are formed in the front and back of the line (Fujita 1956).

5. Concluding Remarks

From the above discussion, the following salient features pertaining to the line type echoes based on the radar study made at Agartala aerodrome during 1964 are revealed—

(*i*) The number of line type echoes detected is maximum (69 per cent) during the monsoon season. The percentage figures during the pre-monsoon and post monsoon seasons are 16 and 15 respectively.

(*ii*) A majority of the lines (60 per cent) appear as broken and the rest as partly or mainly solid lines.

(*iii*) An appreciable number of the lines are generally of 30-70 n. miles in length. The season-wise distribution of the lines 50 n. miles or more in length, during the pre-monsoon, monsoon and post monsoon seasons are 70, 40 and 70 per cent respectively.

(*iv*) The width of the lines is generally between 5 to 10 n. miles.

(*v*) The lines have marked preferences for their orientation during different seasons.

(*vi*) Regarding movement of the lines it has been found that during the pre-monsoon season though a large number of the lines move from N and W directions, instances of movement from other directions are not also rare. During the monsoon and post-monsoon seasons, most of the lines have been found to move from W to E and from S to N respectively. Some correlation though not very satisfactory, has been found between movement of the lines and mean upper winds at different levels, during different seasons.

(*vii*) Most of the lines have been found to last for 3-4 hours.

(*viii*) The lines have been found to form generally in the afternoon in all the seasons. A good number of the lines also form in the early morning hours during the monsoon and late night hours during all the seasons.

(*ix*) The heights of tops associated with these lines have been found to extend generally upto about 9·0 km.

(*x*) It has been observed that on most of the occasions secondary cells develop near the original squall lines. The maximum number of these secondary cells have been found to form ahead of the lines. Secondary cells have also been found to form in the right and left lateral sectors.

6. Acknowledgement

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