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A radar study of premonsoon squall lines over Gangetic West Bengal

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ABSTRACT. Occurrence and life-cycle of premonsoon squall lines in Gangetic West Bengal, their dependence on the surface and upper air meteorological parameters were analysed from other echoes observed at Calcutta for the period 1963-67. Presence of high terrain in Chota Nagpur plateau of Bihar and solar insolation found to be responsible for the initial formation of squall lines. The phenomenon leading to simultaneous appearance of multiple squall lines in different regions and their movement in different directions were discussed. It has been noticed that squall lines move generally in a direction within 040° clockwise of the prevailing wind at 4·5-km level and the corresponding direction of surface squall observed to be within 020° of the direction of movement of squall line.

1. Introduction

During the premonsoon months, the Nor-westers constitute the main weather hazard in Gangetic West Bengal. Issuing of timely warnings for the movement of these squall lines or for the onset of surface squalls for the parked and moored aircraft requires intimate knowledge about the genesis of the primary cumulus cells, their subsequent building up and the direction and speed of the movements of these massive clouds. The present study made with radar and rawin observations aims at understanding the initial growth and development of these clouds in time and space, their lifetime and decay and also their movements, as related to the upper winds.

2. Data

A 3·2 -cm Radar (JRC Type NMD 451A) with peak output power of 250 KW and p.r.f. 300/sec and beam width 1·2° in both horizontal and vertical is in operation round the clock at Dum Dum. The radar is operated every full hour GMT. Half hourly observations are taken when the storms are in the vicinity of the station. All the observations are plotted on polar diagrams. Important developments are also photographed. Radarscope observations, relevant autographic charts, current weather registers and the rawin observations of Dum Dum for the period from 1963 to 1967 have been utilised for this study. It may be mentioned here that only those occasions when well developed squall lines had formed had been taken into consideration.

It is well known that the initial cumulus cells appearing oval or circular on the radarscope under condition of instability and favoured by insolation and other triggers grow, merge together and appear on the radarscope as broken or solid lines. Over the region of study, the lines are generally 75 to 120 km in length (De 1963), though lines as long as 300 km have been observed. They orient themselves in SW/NE, S/N and/ or W/E directions and move generally perpendicular to their orientations. In course of their movements the cold downdrafts injected in the unstable airmass ahead cause regeneration of fresh cells.

3. Initial growth of cells

(*a*) *Distribution in time*—The initial appearance of 55 echoes spread over the time scale are tabulated in Table 1 and it is seen that maximum number of incidences of echoes appear during 6-11 GMT with the highest frequency occurring between 7-10 hours GMT.

(*b*) *Distribution in space* (*sector/distance*)—Fig. 1 shows the distribution of the initial echoes in space. Of the 55 cells which later on developed into well-defined lines, three clusterings, suggesting three preferred zones of convective activities, can be recognised.

(*i*) 29 cells concentrate to constitute a zone (referred to as A) over the area 280°/330°-225 km beyond, *i.e.*, the Chota Nagpur plateau and the adjoining areas of West Bengal.

(*ii*) 9 cells concentrate to constitute a zone (referred to as B) over the area 360°/045°—100/200 km, *i.e.*, West Bengal and adjoining areas of East Pakistan traversed by the *Bhagirathi* (West Bengal), the *Bhairab*, the *Madhumati*, the *Padma* and the *Atarai*—all in East Pakistan.

(*iii*) 5 cells concentrate to constitute a zone

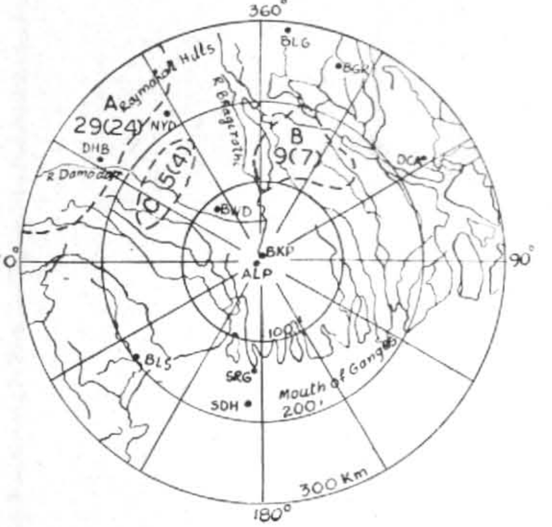

Fig. 1. Diagram showing preferred zones of initial echo formation

Figures in bracket indicate number of thunderstorms recorded at Dum Dum against number of initial echoes in respective zones

(referred to as C) over the area 285°/330°—125/175 km, *i.e.*, the areas of the districts of Bankura, Purulia and Midnapore lying between the *Damodar* and the *Kasai*.

However, the above findings do not preclude the possibility of cell development elsewhere as it has been found (Rakshit 1966) that the whole sector extending from SW to E through N of Dum Dum is favourable for such formation of convective clouds.

The comparative quiescence of convective activity during the period between 1200 and 0600 GMT and their preponderences during 0700 and 1100 GMT as will be evident from Table 1, bring out the importance of insolation as a trigger. The distribution in space suggests the importance of the terrain —the high lands and the river valleys. On the other hand a 200-300 km wide belt extending from 280° to 040° through 330° of Dum Dum is broadly the region where the lines of discontinuities between the low-level southerlies/southwesterlies and the easterlies oscillate during the season. Better association of convective activities with these discontinuities compared to the ones between the northwesterlies/westerlies and the easterlies and the others between the northerlies/westerlies and the southwesterlies/southerlies, the general low level features of the region during the season, have also been suggested by Ramaswamy (1956).

4. Line formation

The time lag between the initial appearances of echoes and the fomation of line type echoes and the life time of the lines are presented in Table 2.

It may be seen that line formations are ensured within two hours of the first appearance of the echoes. It may also be seen that the lines forming rapidly after the initial growth are expected to have great longivity.

5. Formation of double lines

Another interesting feature is the formation of double lines. The following are certain characteristics :

(*i*) Simultaneous appearance in the same zone (in zone A on 27 May 1966) moving in the same direction and with the same speed but one decaying before the other resulting in a single squall at Dum Dum.

(*ii*) Simultaneous appearance in different zones (in zones A/C and B on 9 April 1963 and in zones A and C on 15 April 1963) with unequal movements and lateral growths later merging together and assuming the appearance of a single line resulting in a single squall at Dum Dum.

(*iii*) Appearance in different zones (zones A and B on 3 May 1963) discontinuous in time, moving in different directions with different speed, later merging together and assuming the appearance of a single line resulting in a single squall at Dum Dum.

(*iv*) Appearance in different zones (zones A and B on 29 May 1967), discontinuous in time, moving in same direction though with unequal speed — one decaying earlier and so resulting in a single squall at Dum Dum.

(*v*) Appearance in different zones (zones A and C on 23 March 1965), discontinuous in time moving in different directions and with different speed resulting in double squalls at Dum Dum from different directions and at different hours of the evening.

Outbreaks of premonsoon thunderstorm activities in distinctly different zones, simultaneously or separated by time intervals during the same morning and/or evening in association with distinct local low level velocity convergence fields have also been observed in the eastern states of Assam, Tripura and Manipur (Chaudhury 1961).

6. Length reduction

It has been observed that as the lines move they may increase in length or the length may remain unaltered till the mass starts decaying rather abruptly. But majority of the lines were characterised by gradual reduction in length.

TABLE 1

Hours (GMT)	0	1	2	3	4	5	6	7	8	9	10	11
No. of incidence of echoes	1	—	—	—	1	2	4	7	7	7	7	6
Hours (GMT)	12	13	14	15	16	17	18	19	20	21	22	23
No. of incidence of echoes	3	3	2	—	—	1	—	1	1	—	1	1

TABLE 2

Life time of squall lines

Line formation within	Longivity (hours) of squall lines						
	2	3	4	5	6	7	8
1-hr	1	8	8	7	7	5	1
2-hr	1	2	2	1	5	1	1
3-hr	0	0	1	2	0	0	0
4-hr	0	0	2	0	0	0	0

Examination of length alterations of the 55 squall lines reveals the following:

Increase in length	5
No change in length	9
Reduction from NW	25
Reduction from SW	12
Reduction from E	1
Reduction from both ends	3

It is well known (Byers and Braham 1949) that increase in length of the squall lines is due to triggering of new cells in its leading edges where its cold outflow undercuts the convectively unstable air lying ahead. The erosion of the echoes and the consequent length reduction in the trailing ends at the rear is due to precipitating out of the water droplets responsible for radar-returns and absence of re-generation processes because of relatively weaker cold outflow and the prevailing drier post-squall air there.

The edges towards which the length increases point out the regions of further cell developments where pronounced updrafts and downdrafts will result in appreciable turbulence even though the air at the moment is free of clouds, whereas, the denuding trail under processes of subsidence will be a safe region free from turbulence.

7. Movement of the squall lines

From the plottings of the successive position of the lines on the polar diagrams from their initial appearance on the radarscope to their decay, the average direction and the speed of movement have been calculated. It was observed that in majority of the cases the speed of movement of an individual line remained fairly uniform after the second hour of its appearance. To find out if any steering level existed, comparison of these movements with the wind fields at 3·0, 4·5, 9·0 km and also with the mean resultant wind between 1·5 and 9·0 km (approximate vertical extent of the cumulonimbii) of 00 GMT have been made. Dum Dum wind observations (rawins) have been taken as representative of the prevailing winds over the area. It may be mentioned here that for 44 out of 55 squall lines studied, complete wind observations were available.

For this, departures of direction and speed (cloud movements *minus* upper winds) have been calculated for each level. When the speed of the cloud movement is more than the wind speed the departure has been regarded as positive. Similarly, when the direction of the cloud movement is more clockwise than the wind direction the departure has been regarded as positive and *vice versa*. For example, on 25 March 1963 squall line movement was 285°/43 kt. The wind at 3 km was 240°/17 kt. Hence the departure is worked out as *plus* 45° in direction and *plus* 26 kt in speed. Then from a central "zero" the positive and the negative departures have been scattered away in their respective positive or negative marks. From such scattered diagrams in respect of both direction and speed and for each said level Table 3 has been prepared.

From (a) of Table 3 it will be seen that—

(*a*) The direction of movement of the squall lines is generally clockwise of the direction of the prevailing winds. Such tendencies for large rain storms (squall lines) for deviations from the prevailing wind directions in the cloud layer, as also observed elsewhere, have been discussed by Newton and Katz (1958).

(*b*) Majority of the lines move within 040° (clockwise) of the winds at 3·0, 4·5, 5·4 km and the mean resultant wind (M.R.W.), whereas with 9·0 km level, this correspondence is low—the direction of the cloud movement being further clockwise of the wind.

(*c*) Taking the occasions of negative departures and the occasions of positive departures further

TABLE 3

Movements of squall lines as related to upper winds

Wind levels (km)	(a) No. of cases of direction				(b) No. of cases of speed			
	Within *plus* 040°	Within *minus* 040°	Further of *plus* 040°	Further of *minus* 040°	Within *plus* 10 kt	Within *minus* 10 kt	Further of *plus* 10 kt	Further of *minus* 10 kt
3·0	23	6	15	0	19	10	13	2
4·5	35	4	5	0	19	8	12	5
5·4	23	7	14	0	18	11	6	9
9·0	12	2	30	0	5	7	6	26
M. R. W. between 1·5 & 9·0	24	2	18	0	32	6	5	1

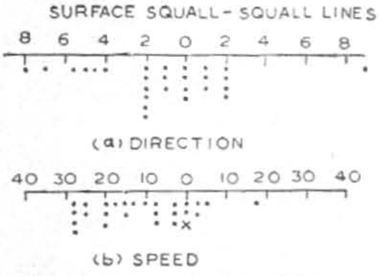

Fig. 2. Departure of movement of squall lines from surface squalls at Dum Dum

Positive to the left and negative to the right

of 040° into consideration, the correspondence between the direction of movements of the squall lines and the wind direction at 4·5-km level is the highest.

(b) of Table 3 reveals that—

(1) Speed of movement of the squall lines is generally higher than the speed of winds at 3·0, 4·5, 5·4 km and also of the M.R.W. but is lower than the speed of wind at 9·0-km level.

(2) Taking the occasions of negative departures and the occasions of positive departures further of 10 kt into consideration, the correspondence between the speed of movements of the squall lines and the speed of the mean resultant wind (1·5 to 9·0 km) is the highest.

8. Surface squalls

Of the 44 squall lines, 27 lines in course of their movements were responsible for causing surface squalls/gusts at Dum Dum in which the speed had exceeded 25 kt. The departures of direction and speed of these surface squalls from those of the squall lines (method discussed under Sec. 7) are shown at (a) and (b) of Fig. 2 respectively.

It may be seen that the surface squalls show a tendency to attain higher speeds than the speed of movement of the squall lines. But regarding directions, in majority of the cases (nearly 75 per cent) the surface squalls were found within *plus* or *minus* 020° of the direction of movement of the squall lines.

9. Concluding Remarks

The present study has brought out certain characteristics which may be useful in forecasting purposes.

(*a*) Majority of squall lines formed in the Gangetic West Bengal during the premonsoon season move downwinds in a direction within 040° clockwise of the prevailing wind at 4·5 km.

(*b*) Speed of movement of squall lines is not uniquely given by the wind at any particular level but it agrees fairly well with the mean resultant wind of the layer 1·5 to 9·0-km level.

(*c*) The direction of surface squalls is found to be within 020° of the direction of movement of squall lines.

(*d*) There is no systematic correlation between the speed of the squall line and the surface squalls experienced at the station.

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