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Regenerative drift of a thunderstorm squall of the southwest monsoon season

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ABSTRACT. A squall line of the southwest monsoon season has been analysed based on the radarscope observations and the prevalent synoptic situations. It was found to have a regenerative drift. It dissipated gradually after travelling some distance over land. The dimension of a single convective cloud cell inferred from a study of the associated changes in the meteorological elements observed at Dum Dum and Alipore appeared to be much in excess of what has been found in the Thunderstorm Project.

1. Introduction

During the southwest monsoon season, occurrence of a typical thunderstorm squall accompanied with sudden wind shift, rise in pressure and fall in temperature and relative humidity is rather rare over northeast India. On 20 September 1954, such a typical squall was experienced at Dum Dum airfield at 2215 IST, the maximum speed reaching 48 mph in a gust. The squall was accompanied with thunderstorm and torrential rain. A similar sequence of phenomena was also observed at Alipore Observatory situated about 10 miles to the southwest of Dum Dum at approximately the same time, while Barrackpore Meteorological Office situated at a distance of about 10 miles to the northwest of Dum Dum reported thunderstorm with a change of surface wind about 75 minutes later. The purpose of this study is to show with the help of observations made by the meteorological radar recently set up at Dum Dum that the phenomena at Alipore, Dum Dum and Barrackpore were not isolated ones but resulted from the passage over these stations of the parts of a squall line about 125 miles long. Besides presenting the radarscope observations revealing the history of development and movement of the squall line since its formation till it passed over Dum Dum, the synoptic situations prevalent at that time have also been discussed.

2. Observations

The observing radar was a Decca type 41, meant for airfield warning purpose, operating on 3 cm wave band and having a peak pulse power of 30 KW (*Indian J. Met. Geophys.* 1954). Because of a narrow beam width and resultant concentration of power in the beam, the radar can detect appreciable precipitation from a maximum distance of 250 miles, of course, when detectable precipitation is above the radar horizon. The display is made on a PPI-scope of a diameter of 12 inches, on which there is provision to read the plan position of the echoes in miles of range and degrees of azimuth with respect to true north. It is unfortunate that the radar is not provided with any photographing arrangement nor any camera was readily available. The echo diagrams shown in Fig. 1 had, therefore, to be obtained from a very careful tracing of the radarscope picture on suitable transparent paper and then drawing the same to scale in a polar diagram.

On the day in question the PPI of the radar showed no markedly regular activity till 1730 IST when some prominent echoes appeared indicating scattered patches of precipitation over the eastern sector of the scanned area and between ranges of 70 miles and 140 miles. Even at this hour there was no regular line formation but the precipitation patches were fairly large. At 1810 IST the picture

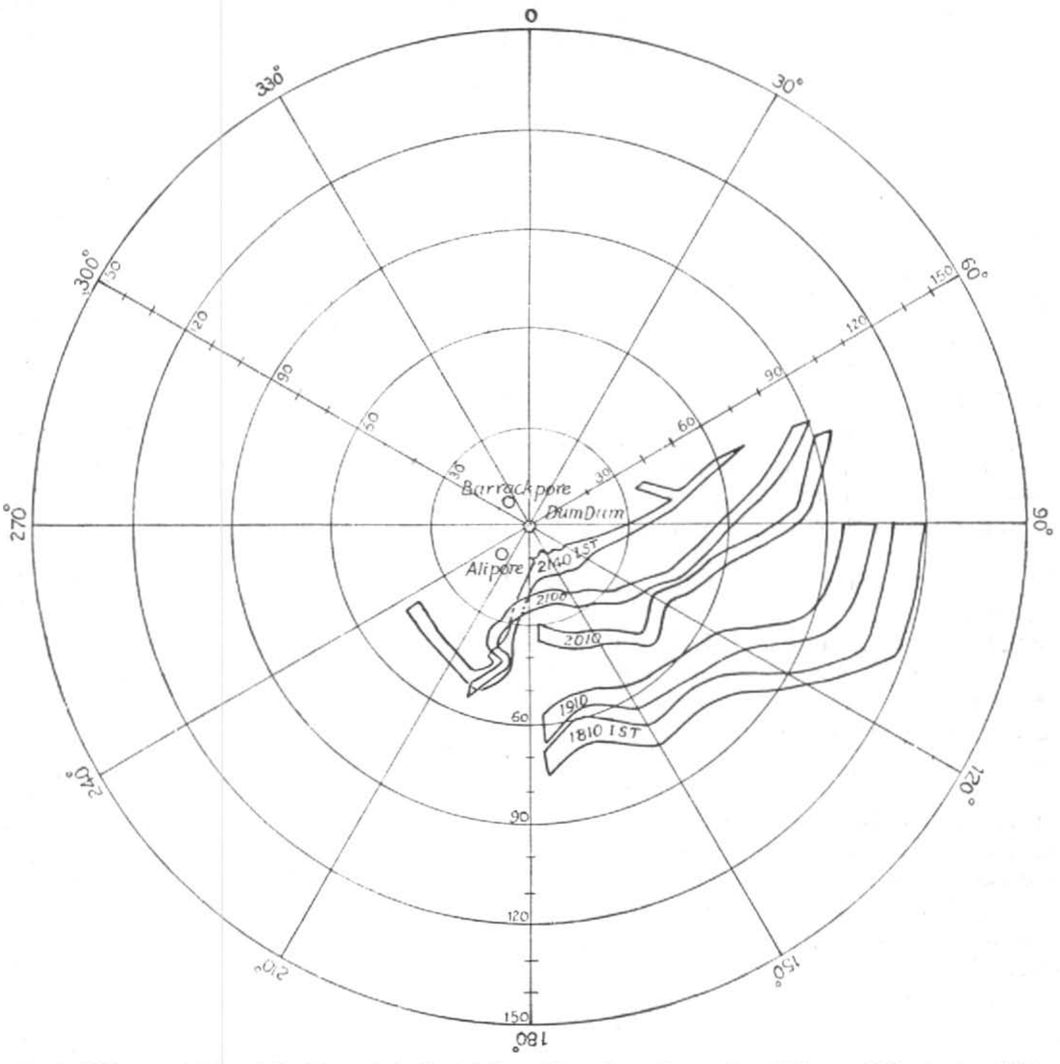

Fig. 1. PPI presentation of the Storm Detecting Radar at Dum Dum Forecasting Office on 20 September 1954

(Radial distances are in nautical miles)

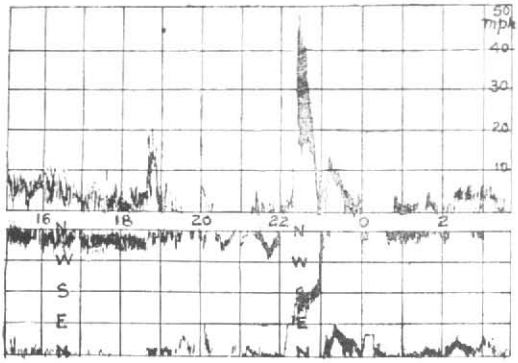

Fig. 2(a). Dines P. T. Anemograph chart—Dum Dum

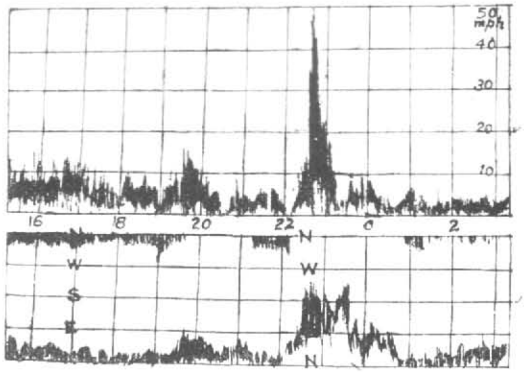

Fig. 2(b). Dines P. T. Anemograph chart—Alipore

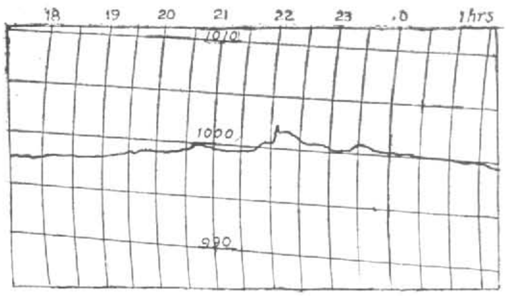

Fig. 2(c). Microbarograph chart—Dum Dum

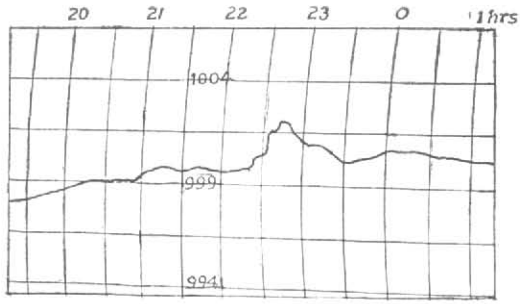

Fig. 2(d). Microbarograph chart—Alipore

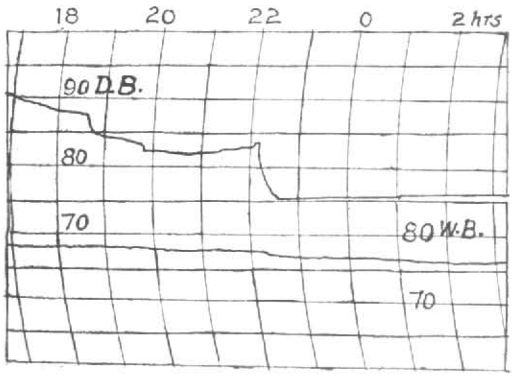

Fig. 2(e). Thermograph chart—Dum Dum

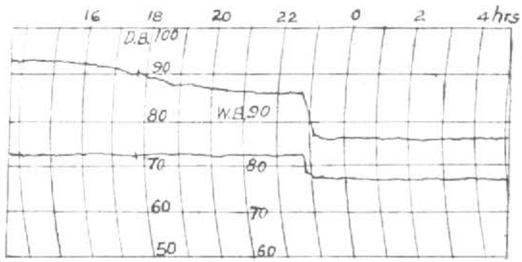

Fig. 2(f). Thermograph chart—Alipore

TABLE 1

Station	Phenomenon with the time of commencement	Duration (min)	Wind at commencement	Maximum wind and time of occurrence	Wind before and after phenomenon	Associated rainfall (inches)	Changes in Pressure (mb)	Changes in Temperature (°F)	Changes in Rel. humidity (%)
Dum Dum	Thunderstorm with squall at 2215 IST	30	SSE 42 mph	SSE 48 mph at 2225 IST	NE/light	0·66	+2·1	—9	—11
Alipore	Thunderstorm with squall at 2212 IST	38	SE 34 mph	SE 51 mph at 2218 IST	N-NE/ light	0·73	+2·0	—9	—9
Barrackpore*	Thunder heard with 4/8 *Cb* at 2230 IST	..	SE 5 mph	..	NE/light	..	..	..	..

*Not equipped with autographic instruments and raingauge

was entirely different, the radarscope showing a distinct well-formed line having a slightly curved structure with ends at (75 miles, 176°) and (120 miles, 90°) †(Fig.1) and an estimated width of 5-10 miles. The striking suddenness with which the line developed eluded continuous observations between 1730 IST and 1810 IST. Later observations showed a steady movement of the line towards Dum Dum, although different parts of the lines appeared to have different speeds of movement which again differed from hour to hour. This is why the line appeared to have different configurations from one observation to another. The PPI diagram of the line at different hours from 1810 to 2140 IST are shown superposed in a single sketch in Fig 1. For convenience of comparision and reference, positions of Alipore and Barrackpore are also shown in this figure.

Table 1 gives the relevant surface observations of Dum Dum, Alipore and Barrackpore.

The records from the autographic instruments at Dum Dum and Alipore are shown in Fig. 2. The autographic records of Alipore are maintained in LMT while those of Dum Dum are maintained in IST. It will be seen that within the limits of accuracy of the crude clock of these autographic instruments and the observer's personal error in initial setting of the charts, the sharp changes in the corresponding meteorological elements seem to have taken place simultaneously at Alipore and Dum Dum, if these records are reduced to same time base. The simultaneity of occurrence of phenomenon at both these places becomes more apparent if the nature and magnitude of change (for which these instruments have much greater accuracy than the time co-ordinate) of the corresponding meteorological elements as shown in Table 1 are taken into account.

3. Discussions

Structure—From the relative positions of Alipore and Barrackpore as shown in the radarscope diagram and the lie of the squall line and its movement (Fig. 1), it is clear that Dum Dum and Alipore were struck by the squall line almost simultaneously. This is further confirmed by the simultaneity of occurrence of squalls at those two places with practically same speed and direction and weather—Figs. 2 (a) and (b). Unfortunately, radar observations are not available beyond 2140 IST. But considering the past movement of the squall line as noticed

†The co-ordinates are miles of radar range, and plan azimuth in degrees

on the radarscope and the fact that at 2230 IST, Barrackpore experienced a thunderstorm associated with a wind shift exactly similar to that of Dum Dum and Alipore, it can be concluded that this line passed over Barrackpore also but had considerably less activity.

Apart from the surface wind peculiarities, the squalls brought about changes in pressure, temperature and humidity typical of thunderstorms. At Dum Dum the barogram—Fig. 2 (c)—shows a practically steady pressure previous to the occurrence of the squall while due to the diurnal tendency it should have risen. With the onset of the squall a well-marked 'nose' appeared. The pressure then remained steady for about 20 minutes representing the characteristic pressure 'dome'. The barogram of Alipore reveals all these features including the pressure dome but the nose was less typical—Fig. 2 (d). The thermograms of both Dum Dum and Alipore show a sharp drop of 9° F with the onset of the squall—Figs. 2 (e) and (f). The hair hygrograph records—Figs. 2 (g) and (h) show the typical 'dip' of about 10 per cent in humidity with the onset of the squall which then rose to near saturation value. The character and intensity of rainfall at Dum Dum and Alipore were also similar—Figs. 2 (i) and (j).

From the study of the above observations and considering the radar picture observed prior to their onset, it may be concluded that they were phenomena on two different parts of the same squall line consisting of a large number of thunderstorm cells laterally arranged close to each other. The striking similarity in character and magnitude of change in the various meteorological elements at Alipore and Dum Dum can be due to either two identical cumulonimbus cells striking Alipore and Dum Dum simultaneously in the identical stage of degeneration or both these stations were affected by the same storm. The first alternative calls for a fortuitous combination of natural forces with identical similitude while the second one leads to the conclusion that the upper limit of dimensions of a single cell over Indian tropical regions may be much larger than that observed in the Thunderstorm Project (*The Thunderstorm* 1949). All large cells of such dimensions have been considered by the Project as consisting of a closely packed cluster of a number of smaller cells. It remains to be seen in India, by means of observations by radar having RHI-scan and otherwise, what is the usual extent and structure of such huge convective storms of our region.

Synoptic situation—The line itself lay approximately in a SW-NE direction practically all throughout its course of movement. The character of the line as revealed by meteorological observations of Alipore and Dum Dum establishes it as a squall line though a clear cold front cannot be discovered on the synoptic charts. In the following paragraphs an attempt is made to show how under the prevailing synoptic situations the squall line came into existence.

Referring to the 1730 IST sea level chart of the day (Fig. 3) it can be seen that a well-marked low pressure area existed over the northeast Bay of Bengal. The most interesting feature of the weather situation lay, however, in the upper wind chart of 1430 IST (Fig. 4). A very well-marked wind discontinuity which may not be between two distinctly different types of air mass existed about 150 miles to the eastsoutheast of Dum Dum at levels between 5000 and 10,000 ft a.s.l. with disturbed wind field aloft. Considering the first observed lie of the line in the echo pattern of the radar at 1810 IST it may be concluded that the above mentioned wind discontinuity became active to give intense precipitation extending to appreciable heights, which may be interpreted as a mild form of a squall line.

For explaining the subsequent movement two different assumptions can be made —(*i*) that the wind discontinuity which was responsible for the squall line actually passed over Dum Dum or (*ii*) that the wind discontinuity did not pass over the stations, though the squall line did, thus indicating a continuous

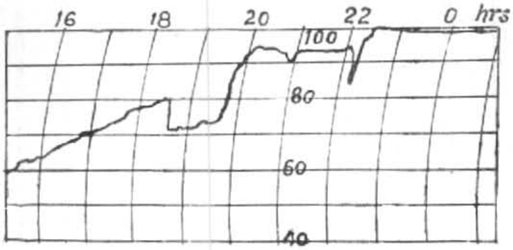

Fig. 2(g). Hair Hygrograph chart—Dum Dum

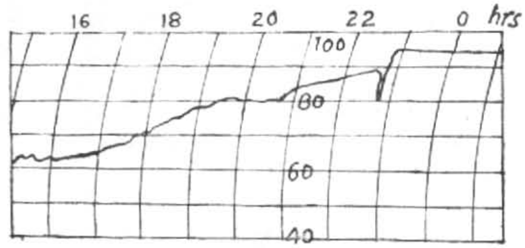

Fig. 2(h). Hair Hygrograph chart—Alipore

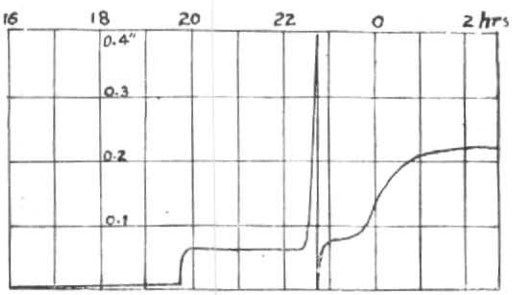

Fig. 2(i). Rainfall chart—Dum Dum

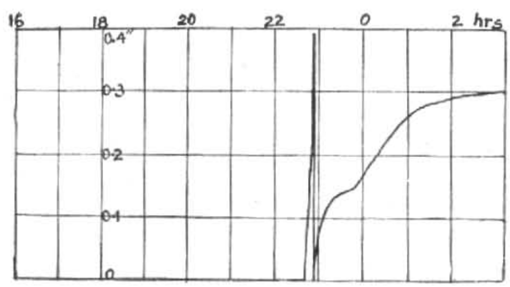

Fig. 2(j) Rainfall chart—Alipore

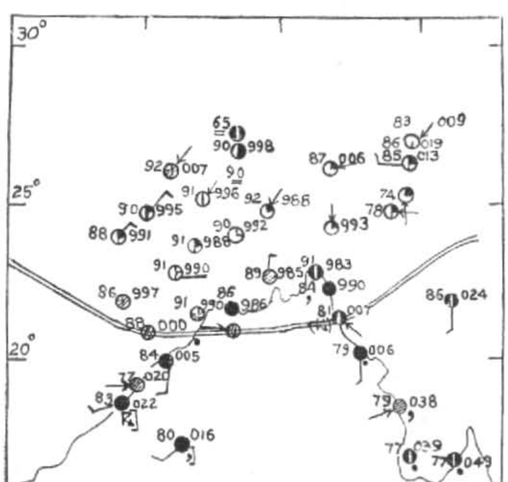

Fig. 3. Weather chart at 1730 IST on 20-9-1954

Wind discontinuity is shown by a double line

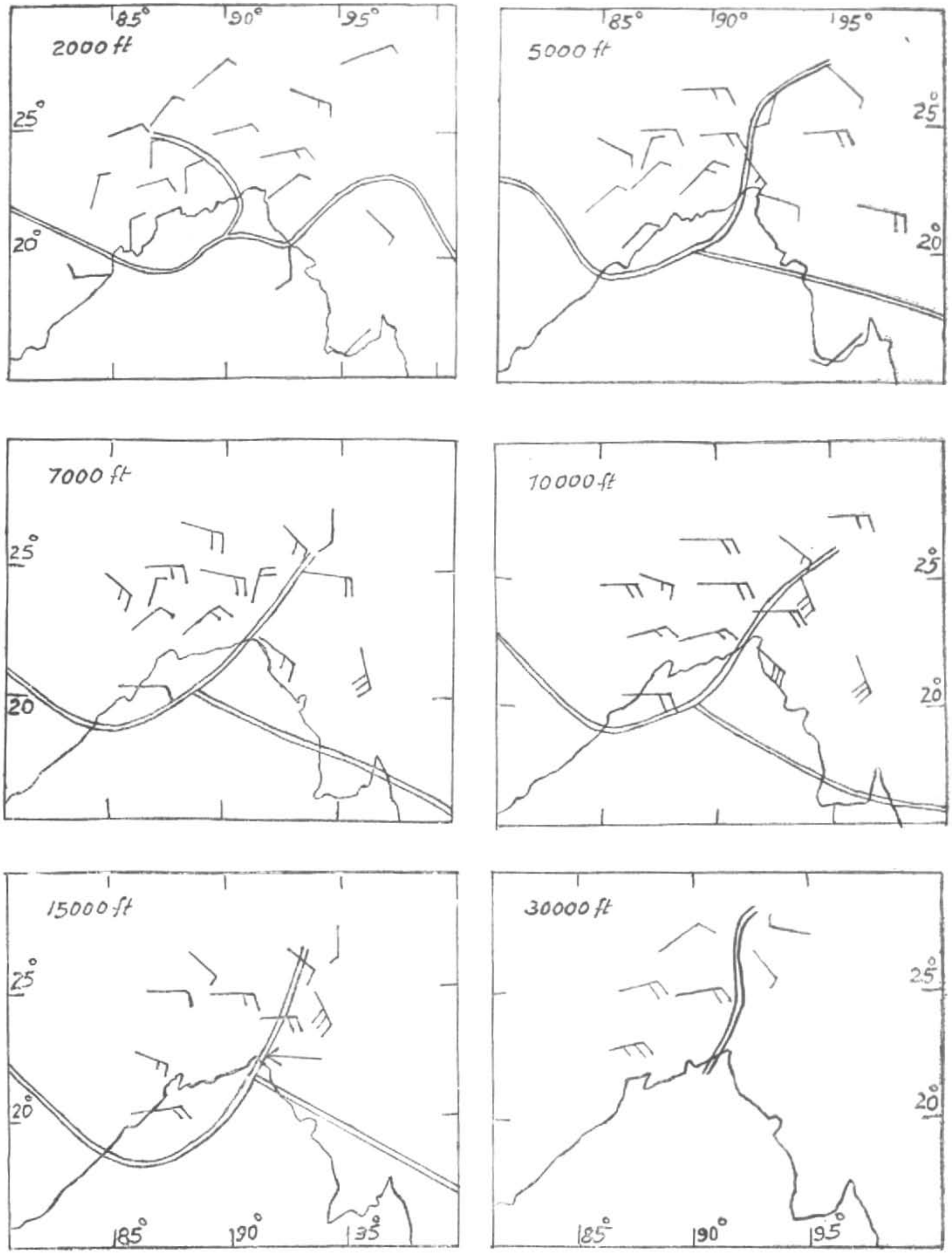

Fig. 4. Upper wind chart at 1430 IST on 20-9-54

Wind discontinuity is shown by double line

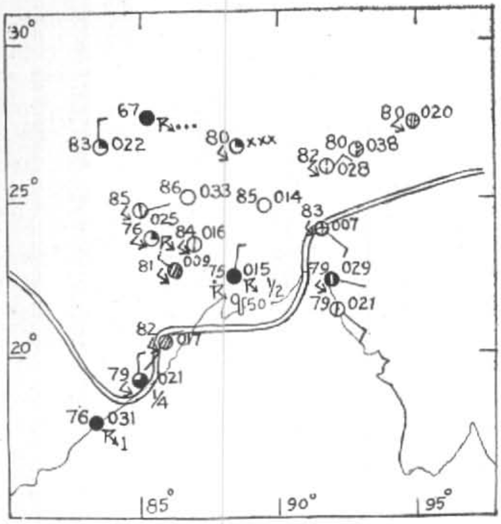

Fig. 5. Weather chart at 2330 IST on 20-9-1954

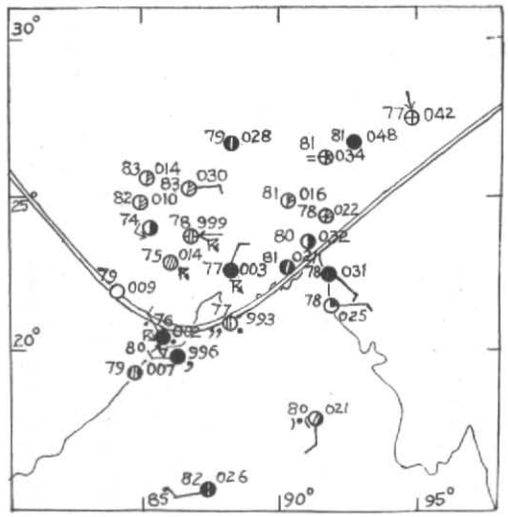

Fig. 6. Weather chart at 0530 IST on 21-9-54

(Wind discontinuity is shown by a double line)

regeneration of the squall line by the outflow of cold air of the down-draft in a forward direction.

Assumption (*i*) may be considered untenable from the following considerations—(*a*) the discontinuity was associated with the low pressure system in the Bay of Bengal, which did not move appreciably westwards between 1730 and 2330 IST (Fig. 5), (*b*) wind returned to N/NE'ly soon after the passage of the squall—Figs. 2(a) and (b) — while on 0530 IST sea level chart of next morning (Fig. 6) the surface wind discontinuity was observed to lie still to the east of Calcutta. It may be argued that the discontinuity giving rise to the phenomena did not build down to the surface and it was the discontinuity at 5000 ft a.s.l. and above that passed over the stations while giving the thundersquall. That this was not the case is indicated by the fact that the discontinuity did later build down to surface, which can be seen from Fig. 6.

Left with assumption (*ii*) we find support in its favour from the conventional theory of building up of new thunderstorm cells by the down-draft from the parent cell (*The Thunderstorm* 1949). This down-draft is found to be most active in a direction perpendicular to the prevailing winds, and the second in importance are the build-ups on the down-wind side. Obviously, when there is a line formation with thunderstorm cells close together on a cold front brought into existence by the down-draft from a number of parent thunderstorm cells also in a line, the maximum formation will be on the down-wind side of the line, thus generating another squall line. In this manner the squall line moves, so to say, in a down-wind direction. This is the well-known regenerative drift of the squall-line or more generally of a thunderstorm cell. It is not a case of pure drift, as without generation of new cells the parent cell would dissipate its energy and become obliterated. It is by generating new cells on the down-wind side that the parent cell appears to move itself. This idea is not at all new, being an actual finding of the Thunderstorm Project, U.S.A. The very same principle was also propounded by Desai and Mull (1938) to explain the movement of the Nor'westers of Bengal. There was, however, no confirmation of the above principle in the radar observation, which then should have shown the new formations in advance of the squall line, but in accordance with what has been pointed out in the Thunderstorm Project, the resolution of the radar may not be sufficient to detect the advance formation since they are quite contiguous to the parent cells.

4. Conclusion

In conclusion it must be pointed out that there is likelihood of slight distortion of the radar pictures as these were sketched in broad outline in the absence of a suitable photographic equipment. Further, since the whole phenomenon was observed between 1810 and 2140 IST, the period over which there are no extensive synoptic observations from a close network over the region concerned, it was not possible to check the position of the squall line revealed by the radar with actual weather observations, in the way done by Ross (1946). Presence of a close network of observatories giving hourly observations over the period in question would have made the conclusion, brought out above, much more well-based. It is interesting, however, to note that a warning for thundersquall over Dum Dum airfield was issued by the Forecasting Officer on duty at Dum Dum on the basis of the relevant radar observations.

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