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Super-refraction conditions at Dum Dum Airport

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ABSTRACT. Conditions for super-refraction have been studied at Dum Dum airport (Calcutta) with a 3-cm radar. There appears to exist some correspondence between the occurrence of ground fog and mist on the one hand and the appearance of super-standard echoes on the other.

1. Introduction

The meteorological conditions leading to super-standard propagation of micro-waves in the lower troposphere have now been fairly well established. Study of such super-standard propagation is mostly made by one-way transmission of micro-waves. Micro-wave radar echoes have also been used with considerable advantage for obtaining a qualitative idea about the super-refracting conditions surrounding the radar. The targets utilised for such observations have been ground and coastal objects. Thus, radar echoes have been obtained at Bombay (height of the radar 255 ft above sea level, optical horizon 20 miles) across the Arabian Sea from as long a distance as 1700 miles. Durst (1946) reports that when such super-standard propagation of radio-waves was observed over the Arabian Sea, the winds at lower levels had a downward component as is usually caused by an anticyclone and inversion. From a knowledge of this extended radar vision and the extent of the normal radar horizon, a qualitative interpretation of the abnormal propagation could be given in terms of super-refraction as would occur under favourable meteorological conditions.

From a detailed study of the profiles of humidity and temperature (in the lowest 1-km level) over land and sea, Sheppard (1946) has found that the lapse of refractive index produced by cloudy weather and strong wind is insufficient to produce enough bending of V.H.F. radio-waves round the earth's curvature. The lapse produced by subsidence, temperature inversion and lapse of vapour pressure is, however, much stronger and may cause sufficient bending. Thus, the meteorological conditions for producing super-refracting conditions in the lower-most troposphere are also the conditions for the formation of fog over inland stations. In fact, interesting relationship between incidence of fog of varying depths and the range of one way micro-wave transmission has been observed by Smith-Rose and Stickland (1946). This relationship can be interpreted as one not between fog and transmission condition directly but between the conditions for the formation of fog and those for the formation of M-inversions or 'ducts'. Since the synoptic conditions which allow an easy development of super-refracting conditions are similar to those as are favourable for formation of fog, the micro-wave radars show some promise of being of use in issuing fog warning. With the help of micro-wave radar observations it is possible for a weather forecaster to keep watch of the progressive development of a synoptic situation which has been identified by him to be favourable for formation of fog, and he can issue precise fog warning at a busy airfield.

2. The purpose and scope of observations

The present observations were started with a view to studying the relationship between the incidence of super-refraction and the conditions for the formation of fog over the airfield at Dum Dum (Calcutta). As is well-known, the pre-requisite for the formation of fog is a ground inversion, the

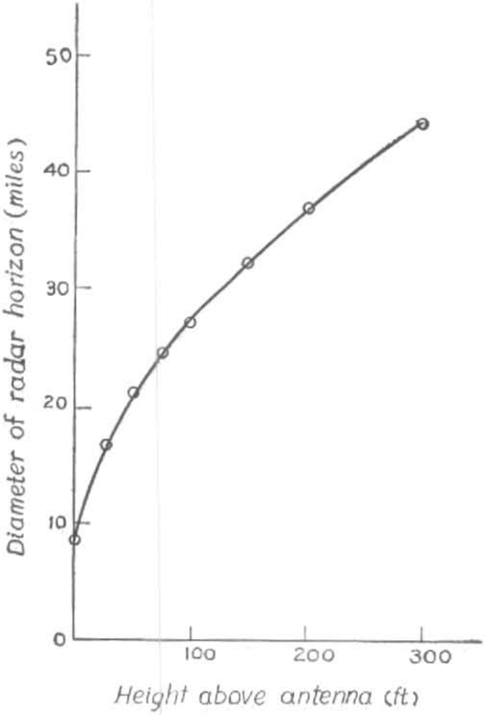

Fig. 1. Variation of radar horizon with antenna height
Surrounding terrain=20 ft a.s.l.
Antenna height=64 ft a.s.l.

depth of which determines the depth of fog. Unfortunately, the progress of changes in the pressure and temperature close to ground with the advance of night cannot be studied with the usual radiosonde instrument because of its high rate of ascent. As such, observations with the usual radiosonde instruments are not of much help to the weather forecaster in the prediction of the incidence of fog. The operation and observations of a PPI radar being simpler it was thought that if a relationship between super-standard reception of ground-clutter on the one hand and incidence of fog on the other could be established it would be of some help in such forecasting. It may be mentioned here that the observations were taken when the radar vision on the PPI scope was found to be extended and or when fog was predicted by the weather forecaster from analysis of the prevailing meteorological condition. The observations, though not sufficient, for drawing any firm generalised conclusion, do throw some light on the occurrence of super-refracting conditions at Dum Dum airfield and its neighbourhood.

3. Description and analysis of observations

The observing radar is a Decca Type 41 meteorological radar, situated at the Dum Dum airport (*Indian J. Met. Geophys.*, 1954, p. 279). The height of the antenna is 64 feet above mean sea level and its optical horizon 10 miles. The radar operates on the 3-cm wave band and has a peak power of 30 kw. The half power beam width is 4° in the vertical. The display is made on a PPI scope of a diameter of 12 inches on which there is a provision to read the plan position of echoes in miles of range and in degrees of azimuth with respect to true North. The method of observation was simply to work the radar set for obtaining a PPI picture of the ground-clutter received at different hours, *e.g.*, 2000, 2200 and 0530 IST. For comparison purposes a PPI picture of the surrounding terrain was first obtained when super-refraction was absent—Fig. 2(a). It may be mentioned that at about 2000 IST a radiosonde ascent was made every night.

The non-standard radar horizon due to super-refraction depends upon the 'duct' height (the height of the M-inversions). But we had no means of estimating the latter from direct observations of the atmospheric conditions. The 'reflection height' was therefore estimated as follows. The transmitted ray was assumed to leave the radar horizontally with respect to the surface of the earth and also arrive at the target tangentially. The height at which 'geometric reflection of the ray' took place was assumed as the virtual height of the reflection of the radar wave. The non-standard radar horizon depends upon the duct height and is different for different duct heights. In Fig. 1, a plot of the radar horizons for different duct heights is shown. It is assumed that the axis of the radar beam is horizontal and the surrounding terrain is level.

Coming to the observations, those during the nights of 12-13, 14-15 and 16-17 February 1955 were indicative of a very shallow ground duct extending the horizon to an average of 12—15 miles (Figs. 2 and 3). This horizon corresponds to a duct height of the order of 10—20 feet above the antenna of the radar The situation remained practically steady during all these nights except for some variations of the horizon and of the intensity of the reflected field-strength. On the night of 15-16th, the observations during the earlier part show some peculiar features—Figs. 3(a), 3(b), 3(c). There is less extension of the radar horizon towards the north than to the south and to the east. At 2200 IST, there is a second set of echoes (which we may describe as a second horizon) about 30 miles to the south and some more echoes towards the east. The picture at 0530 IST was entirely different in nature, with an extension of the horizon more to the north than to the south and with a protrusion towards west. These observations of the 15-16th night offer a very good example of local and temporal irregularities in the lower tropospheric meteorological conditions.

The pictures obtained on 18-19 February show interesting developments of the echoes during the night. The picture of 2010 IST—Fig. 4(a)—indicates a very shallow but very strong ground-duct with some scattered echoes from about 35 miles to the southwest. At 2220 IST these latter echoes gained in number and extended from SSE to WNW with a 'skip zone'. The echoes surrounding the station—Fig 4(b)—due to the ground-duct were still very strong. At 2345 IST—Fig. 4(c)—the outer echoes increased further in number and formed into bands, the echoes close round the station still persisting. At 0540 IST the ground-duct echoes have disappeared but the outer system of echoes has encircled the station with a well-marked skip zone—Fig. 4(d). The echoes forming the ring were very strong indicating a very well formed elevated duct.

The progress of changes on the 19-20th is also interesting. Unfortunately, the midnight observations were not successful. At 2000 IST—Fig. 4(e)—strong echoes have appeared in the southwestern sector at a mean distance of 30 miles corresponding to a reflection height of 130 ft above the antenna. The skip effect is well-marked. At 2155 IST—Fig. 4(f)—these echoes have been replaced by nearer and feebler echoes while fresh echoes have appeared in the southeastern as well as northwestern sectors corresponding to reflection heights lying between 80 and 180 ft. At 0545 IST—Fig. 4(g)—the echoes have taken a regular pattern in the shape of eccentric ring with strong echoes lying between SSW and NNE and the feebler echoes lying in the remaining segment of the ring. Reflection heights indicated are between 180 and 320 ft above the antenna. A summary of the observations together with certain atmospheric data is given in Table 1.

4. Salient features of synoptic situation in winter in the neighbourhood of Dum Dum

In order to understand the significance of the radar observations shown in Table 1, one has to take account of the synoptic situations that prevail over southwest Bengal in winter. Winter over southwest Bengal is characterised by a N/NW'ly flow of tropical continental air at all levels. This tropical continental air is dry and cold and accounts for the low night minimum temperature over this area. The flow of this cold dry air is maintained by an anticyclone over northwest and adjoining central India. Weakening of this anticyclone may be associated with two alternative features. Firstly, there may be a development of an anticyclone cell over the north Bay of Bengal and this inducing flow of moisture over southwest Bengal. Secondly, an East Himalayan anticyclone may maintain an E/NE'ly flow nearly equally dry as the N/NW'ly flow of tropical continental air. It is with the former—the formation of the anticyclone cell over the Bay of Bengal—that most of the fog situations in southwest Bengal are associated.

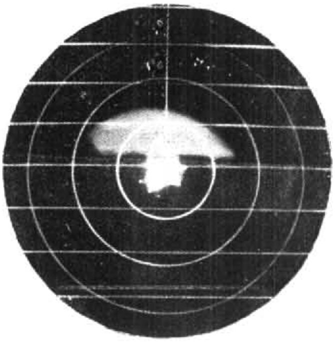

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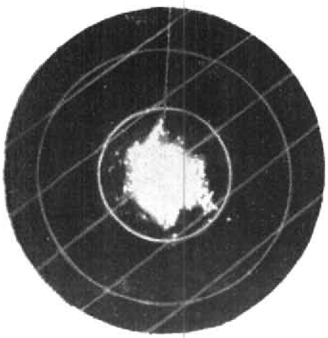
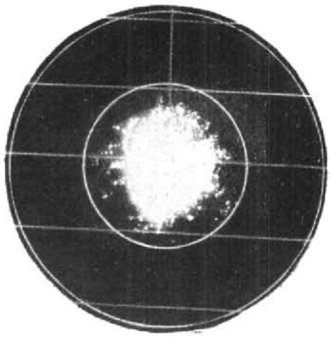
Fig. 2(a). Reference



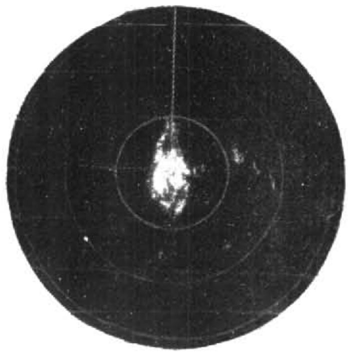
2000 20

Fig. 2(b). 12-2-55



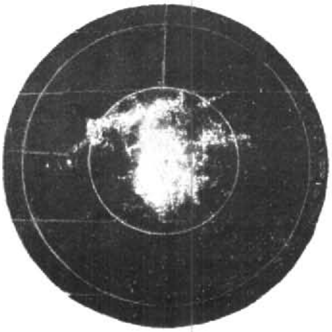
2150 20

Fig. 2(c). 12-2-55



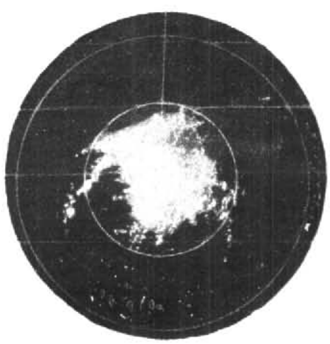
0600 20

Fig. 2(d). 13-2-55



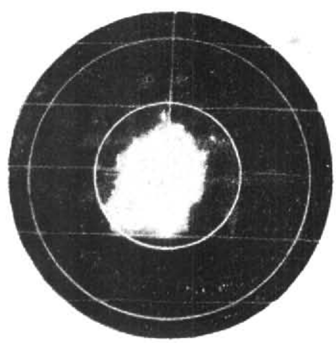
2030 20

Fig. 2(e). 14-2-55



2200 20

Fig. 2(f). 14-2-55

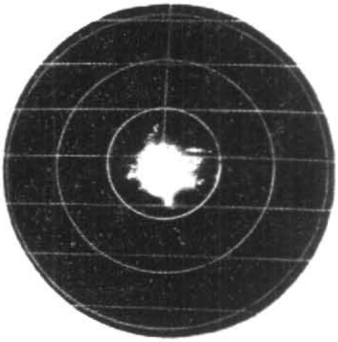


0600 20

Fig. 2(g). 15-2-55

Fig. 2. PPI presentations of the storm detecting radar at Dum Dum Forecasting Office

(The figures in the left and right bottom corners indicate time in IST and range rings in miles respectively. The vertical line represents true North)

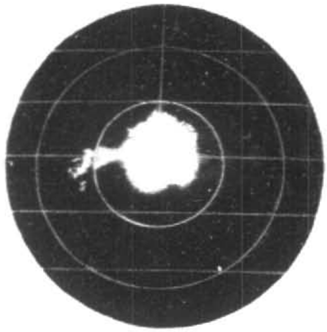


2000 20

Fig. 3(a). 15-2-55

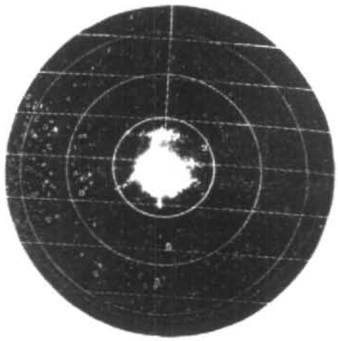
2200 20

Fig. 3(b). 15-2-55



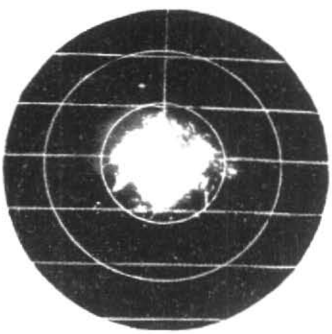
0530 20

Fig. 3(c). 16-2-55



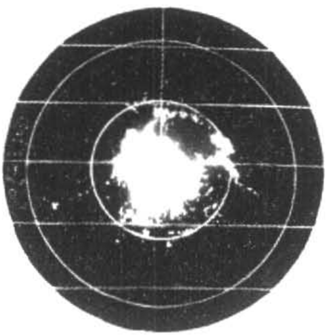
2020 20

Fig. 3(d). 16-2-55



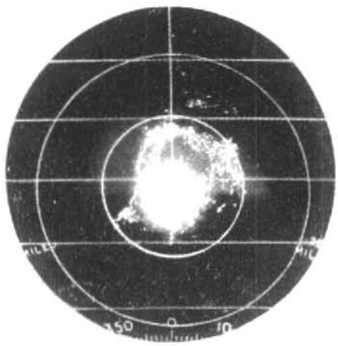
2200 20

Fig. 3(e). 16-2-55



2345 20

Fig. 3(f). 16-2-55



0545 20

Fig. 3(g). 17-2-55

Fig. 3. PPI presentations of the storm detecting radar at Dum Dum Forecasting Office

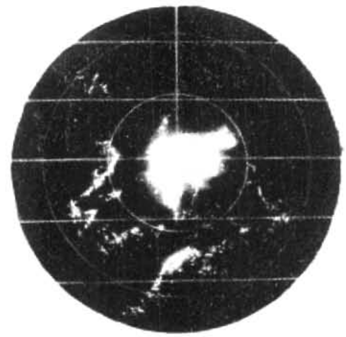
(The figures in the left and right bottom corners indicate time in IST and range rings in miles respectively. The vertical line represents true North)

2010 20

Fig. 4(a). 18-2-55

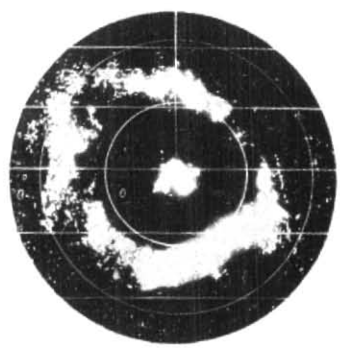
2220 20

Fig. 4(b). 18-2-55



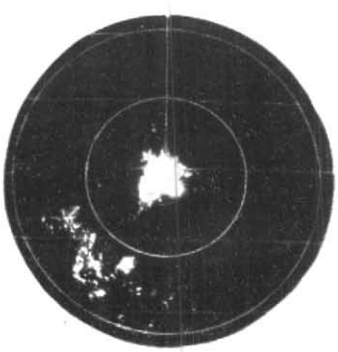
2345 20

Fig. 4(c). 18-2-55



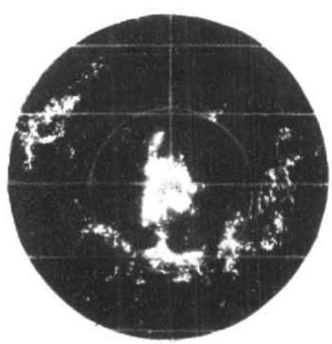
0545 20

Fig. 4(d). 19-2-55



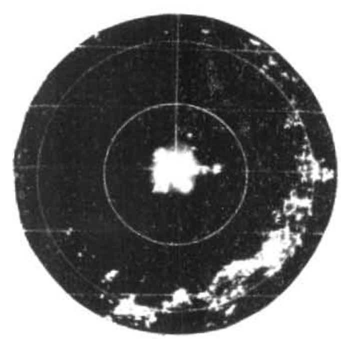
2000 20

Fig. 4(e). 19-2-55



2155 20

Fig. 4(f). 19-2-55



0545 20

Fig. 4(g). 20-2-55

Fig. 4. PPI presentations of the storm detecting radar at Dum Dum Forecasting Office

(The figures in the left and right bottom corners indicate time in IST and range rings in miles respectively. The vertical line represents true North)

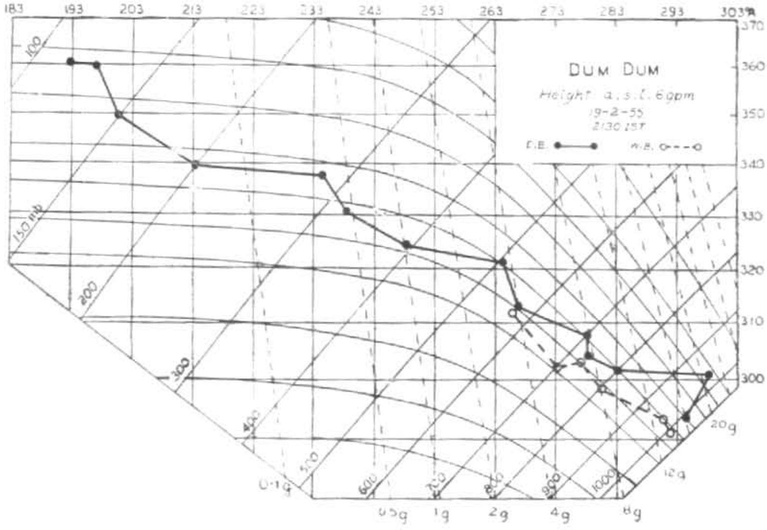

DUM DUM
Height a.s.l. 6gpm
19-2-55
2130 IST
D.B.
W.B.
183
193
203
213
223
233
243
253
263
273
283
293
303°A
370
360
350
340
330
320
310
300
100
150 mb
200
300
400
500
600
700
800
900
1000
0·1g
0·5g
1g
2g
4g
8g
12g
20g

Fig. 5

TABLE 1

Date	Time	Surface wind		Visibility	Approximate height of ground duct above antenna	Approximate height of elevated duct
		Direction	Speed			
	(I.S.T.)	(degrees)	(knot)	(Nautical miles)	(ft)	(ft)
12 February 1955	2000	340	1	5·0	15	..
	2150	..	calm	4·0	15	..
13 February 1955	0600	010	5	1·0	12	..
14 February 1955	2030	360	1	4·0	15-45	..
	2200	..	calm	4·0	15-45	..
15 February 1955	0600	310	1	1·5	15-45	..
	2000	050	1	5·0	10	..
	2200	..	calm	5·0	12	130
16 February 1955	0530	040	2	0·05	15	..
	2020	040	4	4·0	12	..
	2200	060	2	4·0	20	..
	2345	020	1	4·0	15-45	..
18 February 1955	2010	..	calm	5·0	15	..
	2200	..	calm	4·0	15	80-100
	2345	200	1	4·0	15	45-200
19 February 1955	0540	..	calm	3·0	..	80-240
	2000	200	5	3·0	..	130
	2155	210	1	3·0	..	50-180
20 February 1955	0545	360	1	2·0	..	225-300

The anticyclone cell over the northern part of the Bay sends in a shallow surface layer of southerlies over southwest Bengal. A typical example of the temperature and humidity distribution in this situation as obtained from the routine sounding is shown in Fig. 5. Although this sounding does not help us to draw the height-refractive modulus curve which is necessary for the determination of the refractivity of the atmosphere close to the ground, it nevertheless gives us some qualitative idea. If we are allowed to consider these southerlies as 'sea breeze' we can refer for comparison to the soundings obtained by Alexander (1946) of the Radio Development Laboratory, Wellington, New Zealand. He found that when easterly winds flowed in over the west coast near Wellington, targets at a distance of 150 miles were seen by a 10-cm radar. The unorthodox radar vision lasted only so long as the easterly wind persisted; and when the wind dropped the targets also disappeared.

5. Discussions

A reference to the normal climatic maps of Bengal will reveal that during the winter months, continental northerlies/northwesterlies usually prevail over the area. When these northerlies/northwesterlies are replaced by a shallow layer of moisture (upto a height of, say, 1000—2000 ft) bearing winds from some southerly direction, a very steep gradient of decrease in e (aqueous vapour tension) with height is produced near about the transition level between the moist air below and continental air aloft. This will, therefore, produce a very marked gradient of decrease in refractive index near about the transition level leading to conditions favourable for formation of elevated duct.

It should be further remarked that although the formation of an elevated duct is very favourable for fog formation, it is not at all a sufficient condition. The ground moisture content is of utmost importance for producing super-saturation. As a matter of fact, fog happened over Dum Dum on 20 February 1955 morning while there was only mist on the 19th. Conditions of super-standard propagation are linked with conditions for utmost stability which is the necessary condition for fog to form, but without super-saturation no condensation can occur.

The radar observations of the kind reported in this paper may thus be of some use in the pre-warning for fog at a station. The role of the centimetre radar appears to have a good promise in this respect. By showing an elevated duct, it shows the first favourable point for fog. Linking up these observations with the method of temperature forecasting indicated by Basu (1954), great assistance may be obtained for fog warning work.

6. Concluding remarks

The number of observations made in this preliminary study though limited shows that there is some correspondence between the occurrence of ground fog and mist on the one hand and the appearance of super-standard echoes on the other. It is worthwhile making a larger number of observations, under typical situations conducive to the formation of fog, for finding out the correlation coefficient between these two factors. The observations will further show whether this particular type of radar can be of additional aid to a weather forecaster for forecasting incidence of fog and mist.

7. Acknowledgements

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