551·510·52 (541·2)

On the determination of the structure and refractive index of the lower troposphere (lowest 1000 ft) over Dum Dum Airport

A. C. DE

Meteorological Office, Calcutta

(Received 20 August 1958)

ABSTRACT. The results of special radiosonde soundings extending upto 1000 ft made on certain selected dates and at certain selected hours during the winter season 1957-58 and pre-monsoon season 1958 over Dum Dum airport are discussed. The results indicated the formation of ducts at certain hours. The variations of the meteorological data with the progress of night are shown in a tabular form.

The radarscope observations at the corresponding hours are also discussed. On some occasions the duct heights were as high as 600 ft and prevailed for the whole night. These ducts extended horizontally in all directions to about 50 miles. The attenuation produced by appearance of fog/mist over the station and its masking effect on the ground clutters are also discussed. The mass concentration of water droplets on different dates has been calculated and shown in a tabular form.

1. Introduction

In an earlier communication (De 1959) the author has reported the results of some low level radiosonde soundings made over Dum Dum airport, during the winter season 1956-57 and pre-monsoon season 1957. The experiments were limited to the lowest 200 ft level. The results indicated the formation of ducts at certain hours. The formation of these ducts could also be inferred from the PPI scope of storm detecting radar located at the same airport. On two occasions in March and April 1957, the duct heights appeared to be abnormally high and prevailed for the whole night. It was found that the ducts were horizontally stratified and extended in all directions to about 60 miles. Unfortunately, no definite correlation between these duct heights and the M-values calculated from the experimental radiosonde data (limited to 200 ft) could be obtained. In order to find out the correlation, if any, the present sets of observations, as reported in this paper, were carried out.

2. Description of observations

(*a*) *Radiosonde observations*—The radiosonde instrument was held at different levels above the ground. For this purpose a string was wound round a drum, to one end of which was tied the balloon carrying the instrument. The balloon was allowed to rise by steps of 20 ft upto the first 200 ft and then by steps of 100 ft upto 400 ft. From 400 ft the steps were increased to 200 ft upto a maximum limit of 1000 ft level. The radiosonde instrument was held at the step-heights for 2-3 minutes till the meteorological elements of the instrument assumed constant values. The transmitted data were then recorded by the usual radiosonde ground recording equipments.

In order to study the variations of temperature and humidity with the progress of night, the sets of subsequent observations were taken at every alternate hour from 2000 IST till sunrise (2000, 2200, 2400, 0200 and 0400 IST). At 0530 IST a routine radiosonde ascent is taken daily. These data were also utilised along with the experimental data. The experiments were conducted on some selected days during the winter and pre-monsoon months 1957-58 (*i.e.*, from October 1957 to March 1958). The actual dates of observations are given below—20-21 October, 8-9 November, 28-29 December 1957, 16-17 January, 12-13 February, and 3-4, 11-12 March 1958.

(*b*) *Radar observations*—The 3-cm meteorological radar (De *et al.* 1957) is located in the Dum Dum airport area at a distance of about 1100 yards to the SSE of the radiosonde station. The PPI scope pictures were taken at the corresponding hours of the special radiosonde observations, *i.e.*, at 2000, 2200, 2400, 0200, 0400 and 0600 IST.

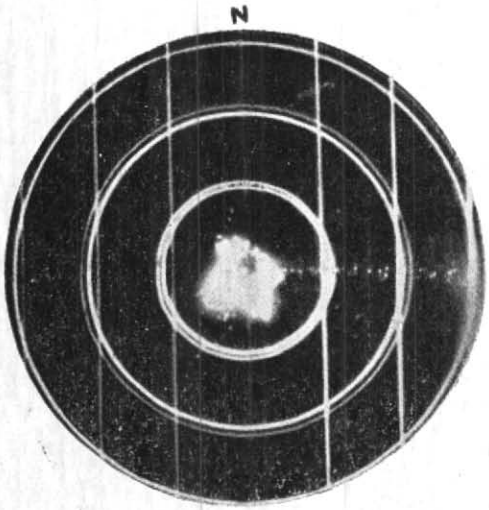
The salient features of super-refraction as observed on the radarscope on the eight nights under discussion are given in Table 1. It is seen from the table that the extended ground clutter echoes appeared at 2000 IST on almost all the days and the number of echoes increased with the advance of night. When the radiative cooling of the ground surface was sufficient and the situation was favourable for the formation of mist, fog, the number of ground clutters decreased. By about midnight or so, the elevated duct started to form when the super-refracted echoes in the form of a ring or line appeared. This phenomenon persisted for the rest of the night till sunrise. After sunrise the elevated M-inversion was gradually destroyed resulting in the disappearance of these super-refracted echoes.

As a typical example, let us consider the situation on the night of 11-12 March 1958. The radarscope observations on this night are reproduced in Fig. 1. At 2000 IST the ground clutters were almost normal. At 2200 IST the ground clutters were slightly extended upto 20 miles in the NNE, S and SW. At 2400 IST the echoes in the form of a partial ring upto 20-40 miles appeared in NE-E-S-W sectors. A small number of echoes appeared at a distance of about 50 miles. At 0200 IST the ring formation was almost complete but the distance was reduced to 20-25 miles only. At 0400 IST the ring type echoes encircled the station in all directions upto 40 miles. At 0600 IST the ring type echoes became less prominent and the echoes also decreased in number.

3. Discussion

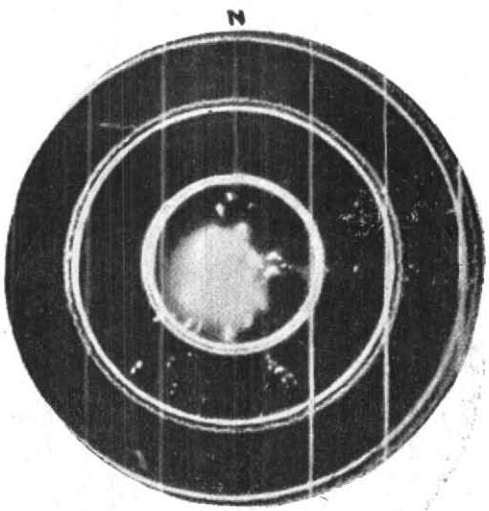
The meteorological factors which are responsible for the formation of radio ducts have been discussed in details by the author (De 1959). From a perusal of Table 1, it may be seen that the ground based M-inversion started appearing by 2000 IST on all days of observations which were responsible for the extension of ground clutters upto about 20 miles. With the advance of night, while these inversions were maintained, elevated M-inversions appeared. The latter were responsible for the appearance of distant echoes which on some occasions appeared in the form of ring.

The situations on the night of 11-12 March 1958 may be taken as a typical example. The M-values at different hours of the night are shown in Fig. 2. The dotted curves show the M-values calculated from routine radiosonde ascents at 1730 IST on 11 March 1958 and at 0600 IST on 12 March 1958. It is seen that there was M-inversion upto 250 ft from ground at 1730 IST on 11 March 1958. At 2000 IST there was ground-based S-shaped M-inversion (Burrows and Attwood 1949) upto 120 ft. This was responsible for the slight extension of ground clutters upto 15 miles (Fig. 1a). The M-values for the layer 120-200 ft were fluctuating. At 2200 IST the ground based S-shaped M-inversion was extended upto 160 ft which resulted in increase of ground clutters. The M-values for the layer 160-200 ft were fluctuating, whence again there was slight inversion up to 300 ft. This was responsible for the scattered echoes beyond 20 miles (Fig. 1b). At 2400 IST the ground based S-shaped M-inversion was decreased to 80 ft only which resulted in the relative decrease of ground clutters (Fig. 1c). If the slight fluctuation of M-values (from 100 to 120 ft and from 180 to 200 ft) are neglected, it is seen that the M-values increased gradually from 80 ft upto 400 ft. There was again slight M-inversion from 400 to 600 ft which was responsible for the ring type echoes upto 40 miles. At 0200 IST the situation was quite interesting. The increase in M-values very close to the ground (lowest 20 ft) which was noticed at 2000 IST and existed till 2400 IST was not present. On the contrary, there was regular decrease



2000 20 M

Fig. 1(a)



2200 20 M

Fig. 1(b)

2400 20 M

Fig. 1(c)

0200 20 M

Fig. 1(d)

Figs. 1(a) to 1(d). PPI presentations of storm detecting radar at Dum Dum airport on 11-12 March 1958

Figures in the left and right hand bottom corners indicate time in IST and range rings in miles respectively

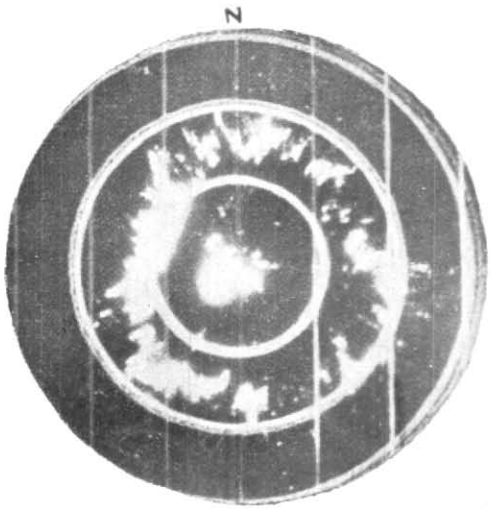


Fig. 1(e)

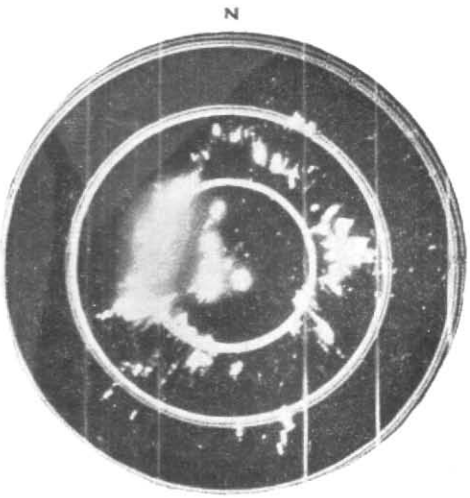


Fig. 1(f)

Figs. 1(e) and 1(f). PPI presentations of storm detecting radar at Dum Dum airport on 12 March 1958

Figures in the left and right hand bottom corners indicate time in IST and range rings in miles respectively

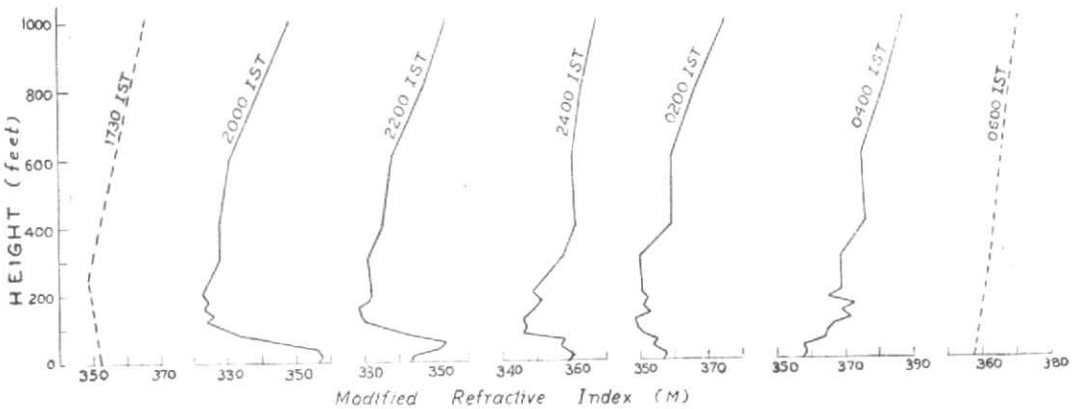


Fig. 2. *M*-values at different hours on the night of 11-12 March 1958

in M-values up to about 100 ft. The gradient was, however, not very steep. The net result was less steep ground-based M–inversion or duct, up to 100 ft which was responsible for the slight increase in ground clutters (Fig. 1d). There was again slight M-inversion from 200-300 ft. This was responsible for the ring type echoes upto 12-25 miles. The elevated M-inversion noticed at 2400 IST between 400 and 600 ft was not present. The M-values at 400 and 600 ft were same. At 0400 IST the ground-based M-inversion was not present and the ground clutters were normal (Fig. 1 e). The M-values at 200 and 300 ft were the same. There was M-inversion from 400 to 600 ft which was responsible for the ring type echoes extending upto 40 miles in all directions. At 0600 IST, there was general reduction in the ground clutters as well as in the ring type echoes (Fig. 1f). The radiosonde observations due to lack of data between ground and 1000 ft, did not indicate the presence of M–inversion, if any, in the region. But from radarscope picture it can be inferred that there must have been M-inversion somewhere between 200 and 600 ft. The decrease of ground clutters was due to the effect of attenuation of radar beam consequent upon the appearance of mist over the airfield.

In order to find out the value of attenuation, the mass concentration (Mc) of water droplets has been calculated in the following way—

Let P = Pressure of the atmospheric air in mb,

e = Vapour pressure in mb,

$P-e$ = Pressure of dry air in mb, and

T = Temperature of air in °K.

Then 1 litre of air under above conditions will occupy

$$\frac{(P-e)\times 273}{1013\times T} \text{ litres at N.T.P.}$$

where normal pressure = 1013 mb, and normal temperature = 273°K.

Therefore, weight of 1 litre of the air

$$= \frac{(P-e)\times 1\cdot 293\times 273}{1013\times T} \text{ gm}$$

$$= \frac{(P-e)\times 273\times 1\cdot 293}{1013\times T\times 10^3} \text{ kg}$$

Hence the volume of 1 kg of the air

$$= \frac{1013\times T\times 10^3}{(P-e)\times 273\times 1\cdot 293} \text{ litres}$$

$$= \frac{1013\times T}{(P-e)\times 273\times 1\cdot 293} \text{ m}^3$$

Now, if x gm/kg be the mixing ratio, the mass concentration

$$Mc = x \div \frac{1013\times T}{(P-e)\times 273\times 1\cdot 293} \text{ gm/m}^3$$

$$= \frac{273\times 1\cdot 293}{1013} \times \frac{x(P-e)}{T} \text{ gm/m}^3$$

$$= 0\cdot 546 \times \frac{x(P-e)}{T} \text{ gm/m}^3$$

The values of mass concentration on different dates as calculated according to the above relation are shown in Table 2. It is seen that the values lie between 10 and 25 which agree quite well with those reported in the earlier communication. These values are much higher than the value assumed by Ryde (1946), *viz.*, 1 gm/m³. Such high value of Mc may be attributed to the moist soil near the Gangetic valley of West Bengal. Assuming these values and using the empirical relation of Ryde (Kerr 1951), *viz.*,

$$\text{Attenuation } (\nu) = \frac{0\cdot 438\times Mc}{\lambda^2}$$

(to an accuracy of 5 per cent),

where λ is the free space wave length (3 cm), the value of attenuation comes out between 0·49 and 1·22 db/km. This value of ν is again higher than that obtained by Ryde (1946) evidently due to higher values of Mc.

From the above discussions one might correlate the duct formation over Dum Dum airport with the echoes as seen on the radarscope. It is noticed that the duct first appeared at about 250 ft at 1730 IST on 11 March 1958 and then the duct height was increased to about 600 ft by 2200-2400 IST. This duct height remained for the whole night till sunrise. These ducts were found to be horizontally stratified in all directions up to about 40–50 miles from Dum Dum airport.

4. Concluding remarks

From the above discussions, it is found that the increase in ground clutters corresponds to the appearance of M-inversion up to a maximum height of 200 ft while the presence of M-inversion up to about 600 ft is responsible for the formation of ring type of echoes. It has also been noticed that the M-inversion was first confined to a shallow layer close to the ground, say up to 100–200 ft, which gradually increased up to 400–600 ft by 2200–2400 IST and continued to remain at that level till about sunrise.

5. Acknowledgements

The author is greatly indebted to Prof. S.K. Mitra, F.R.S., Emeritus Professor of Calcutta University for suggesting the problem. Thanks are also due to the members working in the Radar and Radiosonde sections, Meteorological Office, Calcutta airport, for their valuable assistance and co-operation.

REFERENCES

Burrows, C. R. and Attwood, S. S.	1949	*Radio Wave Propagation*, N.D.R.C. Report, Chap. II, pp. 11–17.
De, A. C.	1959	*Indian J. Met. Geophys.*, **10**, 3, p. 295.
De, A. C. *et al.*	1957	*Ibid.*, **8**, 4, pp. 418–426.
Kerr, Donald E.	1951	M.I.T. Radn. Lab. Series, **13**, Sec. 8·7, p. 676.
Ryde, J. W.	1946	*Phy. Soc. and Roy. met. Soc.*, pp. 169–189.

TABLE 1

Salient features of radarscope pictures and M-values on different dates

Date	Time	Radarscope			M-values	
		Ground clutters max. distance	Distant echoes		Inversion	Same values
	(IST)	(miles)	Distance (miles)	Type	(ft)	(ft)
20-21 Oct 1957	2000	18	50	Scattered	20—60	..
					200—300	
					600—800	
	2200	28	45	,,	20—40	..
					60—80	
					200—400	
	2400	15	35	,,	40—60	..
	0200	15	..	..	20—60	..
	0400	..	45	Scattered	600—800	..
	0600	Reduced	..	..	..	..
8–9 Nov 1957	2000	20	..	..	0—80	..
					100—120	
					300—400	
	2200	20	25	Line	0—60	
					80—100	..
					120—160	
					180—200	
	2400	20	20	,,	0—200	..
					300—400	
	0200	25	40	,,	0—40	..
					80—140	
	0400	25	25	,,	..	0—40
						600—1000
29-30 Nov 1957	2000	18	..	..	0—80	
					100—120	
					140—300	
	2200	15	25	Line	20—60	
					100—120	..
	2400	18	..	..	0—20	
					40—60	
					80—100	
					300—400	
	0200	18	25	Scattered	0—60	
				and line	100—120	
					180—200	
					300—400	

TABLE 1 (*contd*)

Date	Time	Radarscope			*M*-values	
		Ground clutters max. distance (miles)	Distant echoes: Distance (miles)	Distant echoes: Type	Inversion	Same values
	(IST)				(ft)	(ft)
29–30 Nov 1957	0400	15	25	Partial ring	0—60	200—300
					80—160	
	0600	..	30	,,	..	..
28–29 Dec 1957	2200	20	50	Scattered	0—20	
					40—80	
					160—180	
					300—400	
	2400	20	..	..	40—100	
	0200	30	50	Scattered	60—80	
					120—200	
	0400	20	50	,,	20—40	
					120—140	
					160—180	
	0600	20	60	,,	..	..
16–17 Jan 1958	2000	15	50	Partial ring	0—20	
					40—60	
					100—140	
					600—800	
	2200	..	50	,,	0—40	
					140—180	
					800—1000	
	2400	..	40	Line	0—20	
					80—160	
	0200	18	40	Scattered	180—200	
					Missing	
	0400	18	40	,,	0—40	
					120—160	
					180—200	
					300—400	
	0600	22	..	..	0—400	
12–13 Feb 1958	2200	20	50	Scattered	20—80	
					100—120	
					160—180	

TABLE 1 (*contd*)

Date	Time (IST)	Radarscope			*M*-values	
		Ground clutters max. distance (miles)	Distant echoes		Inversion (ft)	Same values (ft)
			Distance (miles)	Type		
12–13 Feb 1958	2400	18	50	Scattered	20—60 80—100 120—140 180—200 800—1000	
	0200	Slightly reduced	50	Partial ring	0—20 60—80 100—120	
	0400	Very much reduced	50	,,	40—60 160—180	
	0600	,,	60	,,	0—400	
3–4 Mar 1958	2000	Reduced	22	Scattered	20—40 80—100 120—160 180—200 300—400	
	2200	,,	25	,,	0—20 80—100 120—160 180—300	
	2400	20	50	Partial ring	0—20	40—60 120—200 800—1000
	0200	22	40	,,	0—80 100—140 160—180 300—600	
	0400	Reduced	40	,,	0—40 60—80 140—160	
	0600	,,	50	Scattered	..	..
11–12 Mar 1958	2000	15	..	..	20—120 140—160 180—200	300—400
	2200	20	50	Scattered ring	60—160 180—300	
	2400	18	50	,,	20—40 60—80 100—120 180—200 400—600	
	0200	20	50	,,	20—40 60—120 140—160 180—300	400—600
	0400	Reduced	50	,,	20—40 120—140 160—180 400—600	200—300
	0600	Very much reduced	50	,,	..	..

TABLE 2

Values of mass concentration Mc on different dates

Date	Time (IST)	Mass concentration (Mc) (gm/m³)	Date	Time (IST)	Mass concentration (Mc) (gm/m³)
20–21 Oct 1957	2000	25·1	16–17 Jan 1958	2000	18·8
	2200	24·1		2200	18·8
	2400	23·0		2400	18·8
	0200	21·8		0200	..
	0400	21·9		0400	15·5
	0530	21·9		0600	14·4
8–9 Nov 1957	2000	19·9	12–13 Feb 1958	2000	15·6
	2200	18·9		2200	14·1
	2400	15·5		2400	13·3
	0200	15·5		0200	12·2
	0400	15·5		0400	12·2
	0530	13·2		0600	12·1
29–30 Nov 1957	2000	22·0	3–4 Mar 1958	2000	22·1
	2200	22·3		2200	20·9
	2400	21·4		2400	19·9
	0200	20·8		0200	18·7
	0400	19·8		0400	18·8
	0530	19·5		0530	18·8
28–29 Dec 1957	2000	13·2	11–12 Mar 1958	2000	20·9
	2200	12·1		2200	18·8
	2400	12·2		2400	17·7
	0200	11·0		0200	16·5
	0400	9·8		0400	15·4
	0600	11·1		0530	15·4