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# Radar echoes from non-precipitating clouds

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ABSTRACT. An interesting example of radar echoes from non-precipitating altocumulus clouds as detected by a high powered 3-cm radar at Dum Dum Airport, Calcutta on 2 March 1965 has been presented in the paper. The heights at which the altocumulus clouds have been formed and thickness of the clouds have been correlated with the physical conditions of the lower atmosphere as revealed by the radiosonde - rawin observations made at Dum Dum Airport. The lenticular shape of the clouds, ascending air current in the centre of the clouds and descending air at the edges have also been revealed by the study. An estimate of the cloud drop diameter (11-14 μ) in the tropical latitudes has also been suggested.

## 1. Introduction

Since the last world war, studies using microwave radar have thrown much light on the structure, movement, development and distribution of different types of clouds. These studies have been mainly confined to the above aspects relating to precipitating clouds, both convective and stratified clouds. Little attempt has been made to study the non-precipitating clouds like altocumulus, stratocumulus etc. The reason for the same may be that the number and size of the precipitating particles inside these clouds might not be sufficient for the detection of the scattered energy by the centimetre radars. For this purpose millimetre radars are highly useful. However, there have been some occasions, though rare, when altocumulus clouds have been detected by centimetre radars.

Instances of detection of altocumulus clouds observed with a high powered (250 KW peak) 3-cm radar (CPS-9) at Delhi have been reported by Mull and Kulshrestha (1961). A high powered (250 KW peak) radar (Japanese NMD 451A) operating on 3-cm wave band was installed at Dum Dum Airport in 1958. Since then continued efforts were made to detect altocumulus clouds on the radarscope, but in vain. However, very recently (on 2 March 1965) an instance has been found when altocumulus clouds in the vicinity of the radar station (Dum Dum Airport) have been detected by the radar. The results of the study is presented in this communication.

## 2. Synoptic situation

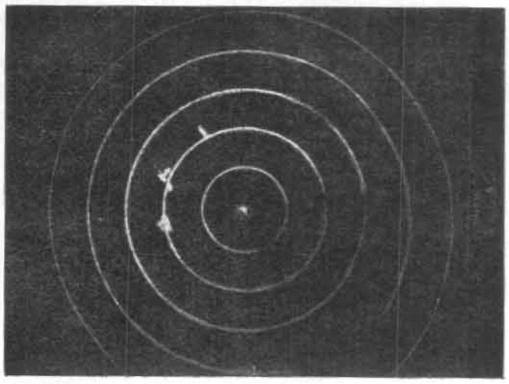
On 2 March 1965 the synoptic situation was favourable for the formation of low and medium clouds in the vicinity of Calcutta. At 03 GMT, the surface chart showed the existence of a shallow low pressure wave to the south of Calcutta. At 06 GMT, the low was reduced to a trough line running almost N-S to the east of Calcutta. At 09 GMT, the trough line moved further east and was oriented in the NE-SW direction. At 00 and 06 GMT, the low level upper winds in the vicinity of Calcutta showed cyclonic circulation upto 5000 ft. A westerly jet stream of speed 60—80 kt was noticed above 20,000 ft. The surface and upper air conditions were thus favourable for the formation of low and medium clouds.

The visual observations as recorded at the Main Meteorological Office at Dum Dum Airport reveal that from 00 to 01 GMT there were 2 oktas altocumulus clouds at an estimated height of 3 km. The amount increased to 5–6 oktas by 03 GMT and decreased again to 3-4 oktas by 11 GMT. Apart from the altocumulus clouds, sometimes 1-2 oktas stratocumulus and cirrus clouds were also observed. The estimated heights of these clouds were 0·9 and 7·5 km respectively.

## 3. Radar observations

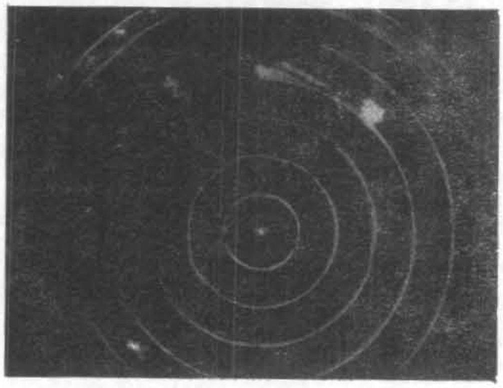
No echo appeared on the radarscope till 0600 GMT. Radar echoes first appeared at 0630 GMT when a few scattered echoes were observed in W-NW-N-NE sectors at 30 to 40 km away from the station. The heights of the base and top of these clouds were 6 and 8 km respectively. At 0800 GMT, the echoes appeared in the NW-N-NE sectors at 30-38 km. Between 09 and 12 GMT, there were a few scattered echoes in different sectors. Apart from the above, echoes were observed over the station as could be seen by tilting up the antenna unit of the radar.

A few significant pictures of the radarscope are shown in Fig. 1. At 0656 GMT a few isolated cells at distances of about 35—45 km to the west were observed on the radarscope when the antenna was tilted to 7° (Fig. 1a). At 0812 GMT (Fig. 1 b) isolated cells at distances of about 40–45 km were observed in the SW, NW-NE sectors. This PPI picture was taken at 10° elevation. The estimated



20 0656 07

Fig. 1(a)



10 0812 10

Fig. 1(b)

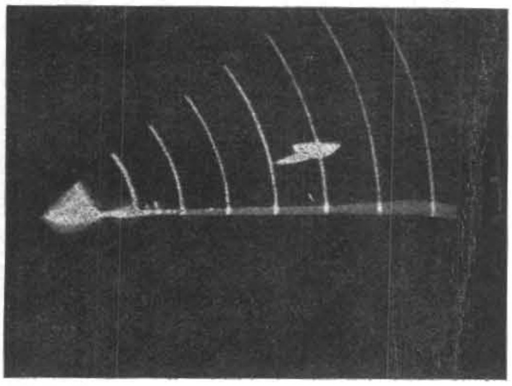


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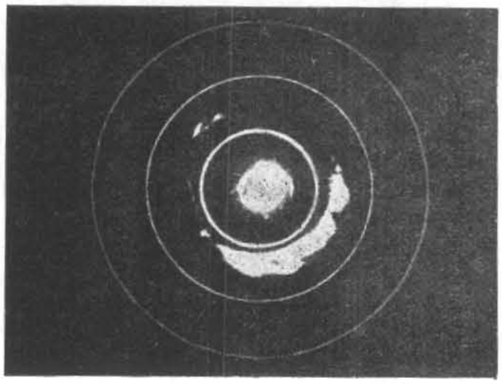
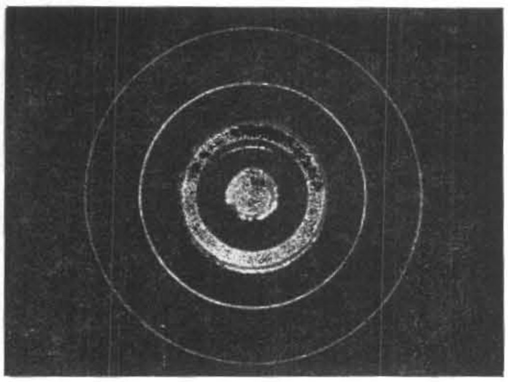
Fig. 1(c)



05 0925 60

Fig. 1(d)



05 0926 90

Fig. 1(e)

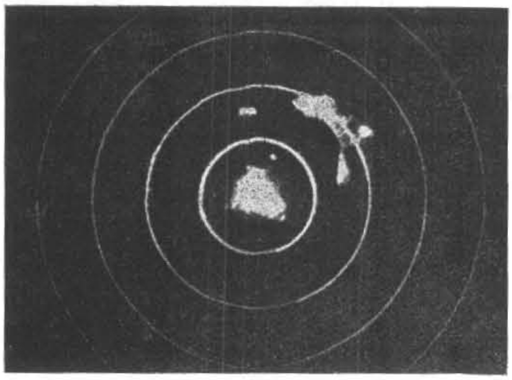


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Fig. 1(f)

**Fig. 1. Radar photographs of altocumulus clouds as observed by NMD 451A JRC radar at Dum Dum Airport on 2 March 1965**

Figures below the photographs indicate (from left to right) range ring intervals in kms, time in GMT and azimuth/elevation in degrees respectively height of the echoes was about 6·8 km. The picture shows the cellular structure of the cloud cells. Fig. 1 (c) shows the REI (Range Elevation Indication) picture taken at 0920 GMT. It is seen that the vertical depth at the centre was more than that at the edges. This can be interpreted to mean that the air in the centre was ascending and that at the edges descending. The PPI picture at 0925 GMT (Fig. 1d) is quite interesting. The picture was taken at 60° elevation. The echoes appeared to be quite intense. The lenticular shape of the cloudlets can also be seen. The overhead picture is shown in Fig. 1(e). The heights of the clouds have been estimated to be 4·9 to 6·5 km. The next picture was taken at 35° elevation (Fig. 1 f). The cellular structure is again observed in this picture.

The Dum Dum radiosonde ascent of 6 hours earlier (00 GMT) indicated conditions favourable for cloud formation at about the level where they later formed (Fig. 2).

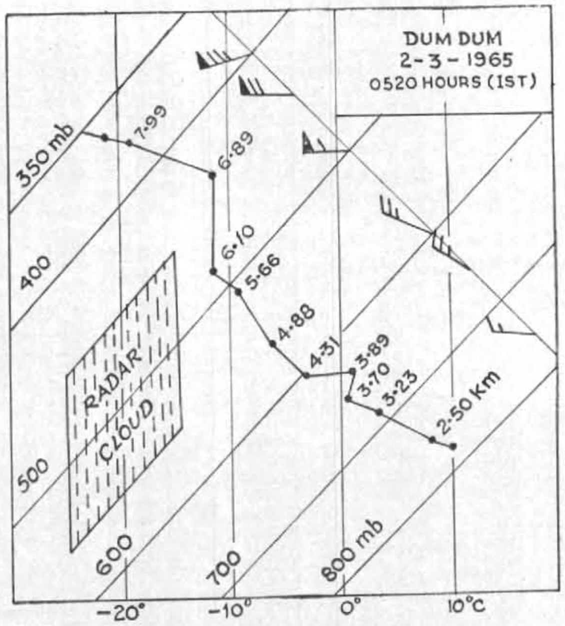

**Fig. 2. 00 GMT upper air radiosonde-rawin soundings taken at Dum Dum Airport on 2 March 1965**

#### 4. Discussion

Since the invention of microwave radars, or more precisely, since the application of microwave radars for meteorological purposes, the radars have been utilised primarily for detection of precipitation particles. In the authors' view, proper attention has not been focussed on the study of non-precipitating clouds, like altocumulus and stratocumulus clouds. The reason may be that the concentration and/or size of water particles inside these clouds is not, on a large number of occasions, sufficiently large for detection by the radar.

Now, it is well known that the sizes of cloud drops depend on the various conditions of cloud formation, *i.e.*, on the mechanism of cloud droplet formation and growth. A detailed and quantitative study on the physics of the cloud-droplet formation has been made by Howell (1949). It has been shown that uniform lifting of air leads to uniform drop-size distribution. The effect of evaporation owing either to warming in descending portions of a cloud or to entrainment of dry air, is a decrease in the concentration of drops. As a result, the highest concentration of drops would be expected in rapidly formed cumulus clouds and the lowest in altocumulus clouds formed slowly by convergence in stable air. However, actual measurements of cloud-drop diameter indicate wide variations for clouds of all types. From a review of the frequency distributions of mean effective drop-diameter, Lewis (1951) has shown that in the Pacific coast region of the United States, the frequency distribution is maximum (28 per cent) in respect of altocumulus clouds of drop diameter 15–19 $\mu$, the value in respect of cumulus/cumulonimbus clouds being 25 per cent. In other regions in the United States, it has been found that the frequency distribution in respect of altocumulus clouds is maximum (32 per cent) for drop-diameter 10–14 $\mu$, the value for cumulus/cumulonimbus clouds being 35 per cent for drop-diameter 15–19 $\mu$. It is interesting to note that there is a slight variation of drop-size with cloud type and a greater variation with geographic location. The average value of drop concentration for altocumulus clouds has been found to be 35/cm³ in the Pacific coast and 75/cm³ in the other regions of the United States, the corresponding value for cumulus/cumulonimbus clouds being 90/cm³ and 160/cm³ respectively. The small average value of drop concentration in altocumulus clouds can be explained by the condensation theory. The larger values for cumulus/cumulonimbus clouds might be due to the greater turbulence and more rapid lifting at the time of condensation.

Let us see if we can measure the size of the cloud droplets with the help of the radar used for the present study. The well known radar equation is —

$$\bar{P}_r = 284 \; \frac{\Sigma D^6}{\lambda^4} \; \frac{P_t \; h \, A_e}{8\pi r^2} \; FK \qquad (1)$$

where $\bar{P}_r$ is the average power received in watts, $P_t$ the transmitted power in watts, $D$ the diameter of the cloud droplets in centimetres, $h$ the pulse length in metres, $A_e$ the effective antenna aperture in metre², $r$ the range in kilometres, $\lambda$ the wave-length in centimetres, $F$ the fraction of the

TABLE 1

| S.N. | No. of drops/cm³ ($n$) | $D$ ($\mu$) |
|---|---|---|
| 1 | 100 | 16·8 |
| 2 | 200 | 15·0 |
| 3 | 300 | 14·0 |
| 4 | 400 | 13·3 |
| 5 | 500 | 12·8 |
| 6 | 1000 | 11·4 |
| 7 | 10000 | 7·8 |

radar beam intercepted by the target and $K$ the attenuation factor. Substituting the values for the radar in use,

$$\bar{P}_r = 10^{-13}\ W,\ P_t = 225\ \text{KW} = 225 \times 10^3\ W,$$

$$A_e = 2.2\ \text{m}^2,\quad h = 300\ \text{m},\ r = 6\ \text{km},$$

$$\lambda = 3\cdot 2\ \text{cm},\quad F = 1$$

(assuming the whole beam being filled with randomly scattered droplets of all sizes at a range of 6 km) and $K = 1$ (assuming no attenuation other than range attenuation), we get

$$\Sigma D^6 = 2\cdot 2464 \times 10^{-21}\ \text{m}^6/\text{m}^3 \qquad (2)$$

Assuming the droplets to be of the same sizes, equation (2) can be written as

$$n\Sigma D^6 = 2\cdot 2464 \times 10^{-21}\ \text{m}^6/\text{m}^3 \qquad (3)$$

where $n$ is the number of particles per unit volume.

Thus substituting different arbitrary values of $n$, we can get the corresponding values of the drop diameter. Table 1 gives different values of $D$ corresponding to arbitrarily chosen values of concentration ($n$).

These values are comparable to those obtained by Mull and Kulshrestha (1961), the values of drop-diameter being slightly larger than those obtained by the latter. Different authors (Best 1957, Diem 1948, Frith 1951, Bricard 1943) have suggested different values of concentration ranging between 300—1000/cm³ for middle latitudes. From Table 1 it is seen that corresponding to these values of $n$, the values of drop-diameter come out to be of the order of 11-14 $\mu$. It is quite likely that in the tropical latitudes the sizes of the cloud-droplets may be larger than those in the middle latitudes. In the light of the discussions made earlier for observations made in the United States, the values of the drop-diameter 11-14 $\mu$ appear quite reasonable. These estimations have, however, to be verified by actual measurements made during the aeroplane flight.

Another important factor which plays a significant role in the radar meteorological study is the liquid water concentration in clouds. Lewis (1951) from a number of flights into different clouds made actual measurements on the liquid water concentration in clouds. He found that in about 82 per cent of the altocumulus-altostratus clouds the liquid water concentration was between 0 to 0·19 gm/m³. He also observed that the lower concentration exists in *Ac* clouds. Taking 0·1 gm/m³ as the mean liquid water concentration for *Ac* clouds and drop diameter between 11-14 $\mu$ with concentration 300—1000 per cm³ the average mass of nucleus for the formation of *Ac* clouds have been found to be between $0\cdot 3 \times 10^{-9}$ gm and $1 \times 10^{-9}$ gm. The value so obtained agrees well with that by Woodcock (1953) who found salt nucleii of mass less than $10^{-8}$ gm at heights of several hundreds' of metres over Hawaii.

## *REFERENCES*


| | | |
|---|---|---|
| Best, A. C. | 1957 | *Physics in Meteorology*, p. 25. |
| Bricard, J. | 1943 | *La Meteorologie*, p. 57. |
| Diem, M. | 1948 | *Met. Rundschau*, 1, p. 261. |
| Frith, R. | 1951 | *Quart. J.R. met. Soc.*, **77**, p. 441. |
| Howell, W. F. | 1949 | *J. Met.*, **6**, pp. 134-149. |
| Lewis, W. | 1951 | *Compendium of Meteorology*, pp. 1197-1203. |
| Mull, S. and Kulshrestha, S. M. | 1961 | *Indian J. Met. Geophys.*, **12**, 2, pp. 243-249. |
| W.M.O. | 1959 | *Tech. Note*, 27, p. 12. |
| Woodcock, A. H. | 1953 | *J. Met.* **10**, p. 362. |