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High Radar Clouds above 10 km

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ABSTRACT. Heights of tops of clouds above 10 km determined by the storm detecting radar at Dum Dum airport during the premonsoon months (March—June) of 1961 have been verified on some occasions by means of post-flight reports from high-level flying aircrafts. Occasionally, the radar clouds have been found to penetrate the tropopause and lower stratosphere. Instances of such cases reported by radiometeorologists in other countries have also been mentioned.

1. Introduction

In an earlier communication (De 1959), an instance of unusually high Nor'wester radar cloud has been presented. It has been shown that the radarscope picture of thunderstorm cloud very near the observing station (Dum Dum) during the premonsoon season of 1958 extended to as high as 22-23 km. The instance was an unusual one, because the radar clouds observed at Dum Dum airport generally extend to a maximum height of about 15-16 km.

Since publication of the above report, the author has received a number of communications from India and abroad about recurrence of such unusually high radar clouds, reliability of the height information, verification of the radar cloud heights by direct method (*viz.*, aircraft observations), associated weather phenomena observed on the ground, etc. In view of these, attempts have been made to verify the radar cloud heights by means of post-flight reports from high-level flying aircraft.

2. Data used

(*a*) *Radar data*—A high powered (250 kw peak) 3 cm radar, Japanese type NMD-451A, was installed at Dum Dum airport (Calcutta) in 1958. It has a beam width of 1·2° in both horizontal and vertical. The radar operates as a routine for about 15 minutes every hour round the clock. The radarscope observations (PPI, REI and RHI) are recorded in a register. Photographs of some important occasions are also taken. The radar data utilised for this study are based on the radarscope pictures during the summer months (March—June) 1961 when the radar clouds extended to 10 km (33,000 ft) or above.

(*b*) *Aircraft data*—High level jet aircrafts often operate through Dum Dum. According to International Procedures, the aircrafts supply post-flight reports about the weather conditions encountered during their flights. Only those occasions when the aircrafts were flying through or very near the clouds at the time of the radar observations have been considered in this study.

(*c*) *Analysis of the data*—There were 188 occasions when the radar clouds extended upto 10 km and above during the period under study, as shown below—

March	1961	29
April	,,	10
May	,,	61
June	,,	88

Out of these occasions, aircraft reports extending to such heights were available on only 6 occasions. The resaons for such small number of occasions are given below. High-level flying aircrafts lose their flying level sufficiently ahead of the landing aerodrome. As such, when they enter the range of the radar (300 km in this particular case), their flight level is so low that their estimated

TABLE 1

Serial No.	Date	Time (IST)	Radarscope			Aircraft reports				
			Azimuth (°N)	Range (km)	Max. height of top of radar cloud (km)	Call sign of aircraft	Route	Position of aircraft	Flight level (km)	Estimated height of top of cloud (km)
1	9-4-61	1130	270/80		10·0	Quantas No. 578	Karachi-Calcutta	Near Calcutta	10·3	10·7
2	2-5-61	1245	279/25		14·0	VIX (IAC)	Madras-Calcutta	,,	5·5	12·5
3	21-5-61	1000	270/30		15·0	Quantas No. 578	Karachi-Calcutta	,,	9·1	13·0
4	25-5-61	1115	052/65		12·5	PDI (BOAC)	Hongkong-Calcutta	,,	10·7	12·0
5	5-6-61	1220	286/60		11·0	VJC (IAC)	Bombay-Calcutta	,,	5·1	11·0
6	27-6-61	1415	255/80		13·0	VJB (IAC)	Madras-Calcutta	,,	4·6	13.0

information about the radar cloud heights may not be regarded as reasonably accurate. The time of radar observations may not be synchronous with the aircraft movement. The occasions when the time difference between the radar observation and the aircraft report is more than 10 minutes, have not been taken into account. The above reasons probably account for the small number of aircraft reports.

The details about the radar observations and aircraft reports are shown in Table 1. It is seen that the heights of tops of radar clouds generally agree with the heights estimated by the aircraft pilots. It is worthwhile to mention in this connection that on quite a large number of occasions the pilots have confirmed the heights of tops of radar clouds while giving their debriefing reports after landing at Dum Dum airport. These debriefing reports have not been incorporated in this study since these were only verbal and have not been recorded.

Though radar cloud as high as 22-23 km has been obtained at Dum Dum airport only once so far, radar cloud tops extending to 18-20 km have been observed by others. Rao (1955) has studied pilot reports of comet aircraft movement in India during 1952 and 1953 and found the extreme height of visual cloud to be of the order of 50,000 ft (15 km), while Deshpande (1961) based on Jet aircraft observations indicated maximum height of top of one out of 187 visual clouds to be above 55,000 ft (17 km). Kulshrestha (1961) studied seasonal distribution of tops of radar clouds at Delhi and reported heights of the order of 61,000 ft (19 km). Mani and Venkiteshwaran (1961) observed that in the vicinity of Poona, the radar clouds sometimes extend to a height of about 45,000 ft (14 km).

Instances of unusually high radar clouds have also been reported in other countries. Arnold (1962) has reported that in Texas, radar clouds have been found to extend to 77,000 ft (23 km). His report was based on

observations made in spring of 1960 with a high powered 3-cm radar set (CPS-9). During the operation of the Thunderstorm Project (1949) a height of top of radar clouds measured with a low powered 3-cm radar set (TPS-10) at Ohio was found to be of the order of 56,000 ft (17 km). Vonnegut and Moore (1958) estimated the maximum cloud top of the Worcester, Massachusetts tornado of 1953 to extend to 65,000 ft (20 km).

It is well known that the height of the visual cloud is more than that of the radar cloud. De and Rakshit (1961) reported that the heights of tops of the visual cumulus clouds as observed at Dum Dum airport during the monsoon season are about 3000 ft more than those of the radar clouds. This means that the maximum height of the visual clouds observed by De (1959) and Arnold (1962) could be 24-25 km.

It is evident that the cases when the heights of tops of clouds observed on the radar were unusually high, the cloud tops must have penetrated the tropopause by about 20,000 ft or more and entered the stratosphere (Jordan 1962). This may be feasible if the tropopause is not well defined and the upward convection is sufficiently strong. Vonnegut and Moore (1958) computed, on certain assumptions, the maximum updraft speed required to push the cloud cells to the maximum height and found it to be of the order of 270 knots. Similar calculations give the values of 250 knots and 350 knots in the cases reported by De (1959) and Arnold (1962) respectively. The cloud top temperatures have been estimated to be about —115°C, —140°C and —135°C in these three cases (Jordan 1962).

The instance reported by De (1959) shows very well defined edges of the radar clouds even at a height of 22-23 km. It is known that the radar reflectivity of water droplet is much more than that of ice/snow particles. The sharp edges of the radar photographs, therefore, seem to indicate that supercooled water droplets have probably been carried by the severe updrafts to the top where the temperature was about —140°C (according to Vonnegut and Moore). Saunders (1962) has suggested some modifications to the approach of Vonnegut and Moore. If we accept his modifications, the updraft speeds come out to be much less and the temperature values at the top of these clouds also become slightly higher. Even then the extent of penetration of cloud tops above the tropopause is 20,000 ft or more.

Recent studies have indicated the presence of appreciable amount of water vapour in the lower stratosphere (Brown *et al.* 1961, Murcray *et al.* 1962). It is possible that occasionally transport of water vapour to the stratosphere has been caused by strong vertical updrafts described above. It should, however, be stated that the heights of clouds as measured by radar may suffer from errors due to the effect of beam width, non-linear propagation of the radar beam (due to the effect of refractive index), curvature of the earth etc. These various possible sources of error and uncertainty should be properly accounted for while reporting radar cloud heights. Sometimes the error may be as high as 10 per cent of the reported echo heights. This will evidently lead to erroneous conclusions. If, however, the beam width of the radar be sufficiently narrow and the cloud is located near the radar station, as in the case presented by the author (De 1959), the effect of the above factors will not be appreciable.

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