

Heights of cumulonimbus cloud tops over the Brahmaputra valley (Assam) : A radar study

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ABSTRACT. Recent information, though not very adequate, about cumulonimbus cloud heights are available in India, from post flight reports of civil jet airliners and meteorological reconnaissance flights organised by the Indian Air Force. In the present paper, results of radar study of the heights of *Cb* cloud tops in the Brahmaputra valley, based on hourly radarscope observations, for pre-monsoon and monsoon months of 1967, 1968, 1969 and 1970 have been reported.

1. Introduction

1.1. The importance of cumulonimbus cloud so far as safety of air navigation is concerned, can hardly be over emphasised.

1.2. Very little information is available in India about the heights of cumulonimbus cloud tops. Despite the importance of precise knowledge about the heights of cumulonimbus tops, no appreciable information could be collected due to lack of observational data. Of late, however, some data have been made available based either on debriefing reports from jet airlines or on limited number of meteorological reconnaissance flight observations. In this part of India (NE India), though famous for violent cumulonimbus activity, very little information is available about height of cumulonimbus tops due to lack of jet airliner operations and aircraft reconnaissance data.

1.3. In view of these limitations it is felt by the present author to undertake this study, to obtain additional data on heights of cumulonimbus cloud tops by the help of a radar.

1.4. In India reports of heights of cumulonimbus tops were first prepared by Ramamurthi (1955). Deshpande (1961) studied 70 cases of *Cb* tops reported by IAF reconnaissance flight B.O.A.C., Comets and other scheduled services for the pre-monsoon, monsoon and postmonsoon seasons of 1958-59. In an earlier study, Kulshrestha (1962) recorded the results of a study of heights of cumulonimbus cloud tops over north India based on observations made

with a high powered radar at New Delhi. A similar study was published by Bhattacharyya and De (1966), for Gangetic valley of West Bengal. Some workers (Venkateswara Rao 1955) studied Comet debriefing reports for a sufficient number of cases (187 cases). Deshpande (1964) studied mean heights of tops of *Cb* clouds and their diurnal and regional variations and weather phenomena in their vicinity, based on data available from meteorological reconnaissance flights and civil flights debriefing reports for six monsoons, all over India.

2. Data

The present study is based on PPI scope observations made with 3.2 cm low power (20 kw) Bendix Radar, installed at Gauhati Airport. The maximum range of the radar is 100 miles and the radar thus gives a representative picture of cloud tops over an area of about 31,000 sq. miles around Gauhati Airport. The radar is operated every hour on a routine basis and a record of all observations including position, orientation and height of the top of cloud, is maintained in a register. Photographs of tall cumulonimbus clouds are taken whenever such cases occur. Convective clouds of heights less than 6.0 km have not been considered for the study. The available data for as many as 7100 cases of cumulonimbus clouds during the summer months (pre-monsoon and monsoon) of 1967 to 1970, have been studied.

Table 1 gives details of cases studied in different months of the different years.

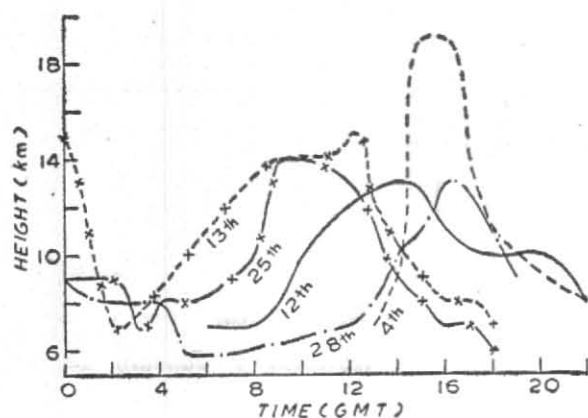


Fig. 1

Development of radar cloud tops during different periods of the day

TABLE 1

Number of occasions of radar cloud tops reaching different heights during various months

	Height groups (km)					Total
	6.1-7.0	7.1-9.0	9.1-11.0	11.1-13.0	13.0 Above	
1967						
Mar	46	24	3	1	1	75
Apr	136	65	24	8	4	237
May	324	135	40	3	0	502
Jun	317	93	25	2	1	438
Jul	209	40	12	1	0	262
Aug	330	84	29	7	0	450
Sep	235	80	19	1	1	336
1968						
Mar	44	4	0	0	0	48
Apr	220	110	54	19	3	406
May	339	191	63	25	23	641
Jun	450	174	34	3	3	664
Jul	523	202	9	0	0	734
Aug	489	300	31	4	1	825
Sep	Radar U/S	Data not available				
1969						
Mar	102	15	1	0	0	119
Apr	176	82	25	8	1	292
May	175	26	3	0	0	204
Jun	61	3	0	1	0	65
Jul	117	30	4	0	0	153
Aug	76	12	1	0	1	90
Sep	53	5	1	0	0	59
1970						
Mar	37	25	10	1	0	73
Apr	112	55	33	4	3	207
May	136	57	16	8	3	220
Jun	34	19	4	0	0	57

3. Data processing

In Fig. 1, some of the more important thunderstorms, in the month of May 1968, have been followed through their entire life history. Date of formation of individual cells have been recorded in Fig. 1 as 4th, 12th etc against time (GMT) of formation and subsequent development as abscissa and height (km) as ordinate. To avoid clumsiness all *Cb* cells in that month have not been recorded in the graph. During the period under study, there were occasions when data was not available due to unavailability of radar at Gauhati.

It will also be seen (Fig. 1) that the maximum height of a cloud is reached during evening (1600-2000 IST, *i. e.*, 1030-1430 GMT) and night (2000-2400 IST, *i. e.*, 1430-1830 GMT). Clouds with tops reaching upto 19.0 km have been recorded.

3.1. The hot weather season for which the data has been studied have been divided into two groups, *viz.*, (1) pre-monsoon, *i. e.*, March to May and (2) monsoon, *i. e.*, June to September.

3.2. As the development of cloud tops is different during different periods of the day for the same season, even to study the diurnal variation of the height of cloud tops, a day has been subdivided into six significant periods such as—

(i) Early morning (0001-0400 IST), (ii) Morning (0401-0800 IST), (iii) Noon (0801-1200 IST), (iv) Afternoon (1201-1600), (v) Evening (1601-2000) IST, and (vi) Night (2001-2400 IST).

3.3. The percentage frequency distribution, of different height intervals, of the cloud tops, during various periods of the day in the two seasons have been presented in Table 2. The consolidated percentage frequency distribution irrespective of the height intervals have been worked out and presented in Table 4.

4. Analysis

4.1. The study gives statistics of cloud tops over northeast India in general and over Brahmaputra valley in particular, during the pre-monsoon and the monsoon. It will be seen from Table 3 that maximum number of clouds in pre-monsoon and monsoon fall in the height group of 6.1 to 7.0 km. More than 60 per cent of the total cloud formations in pre-monsoon fall in the above height group and in monsoon the percentage shoots upto more than 70 per cent. At the same time only 1.2 per cent occasions in pre-monsoon and 0.2 per cent occasion in monsoon, cloud tops reach more than 13 km.

TABLE 2
Frequency distribution of cumulonimbus cloud tops reaching different height intervals during different parts of the day

	Height intervals (km)									
	6.1— 7.0	7.1— 9.0	9.1— 11.0	11.1— 13.0	Above 13.0	6.1— 7.0	7.1— 9.0	9.1— 11.0	11.1— 13.0	Above 13.0
	Pre-monsoon (March-May)					Monsoon (June-September)				
Early morning (0001—0400 IST)	257	111	36	4	2	326	109	19	1	1
Morning (0401—0800 IST)	208	79	16	9	1	383	99	15	0	1
Noon (0801—1200 IST)	277	81	25	3	2	520	146	12	1	0
Afternoon (1201—1600 IST)	465	178	78	14	13	698	273	41	6	2
Evening (1601—2000 IST)	336	172	71	25	12	509	234	33	4	2
Night (2001—2400 IST)	304	168	45	22	8	427	162	45	7	1

TABLE 3

Frequency distribution of *Cb* cloud tops of different height intervals during pre-monsoon and monsoon seasons

Height groups (km)	Pre-monsoon (March-May)		Monsoon (Jun-Sep)	
	No. of cases	Frequency (%)	No. of cases	Frequency (%)
6.1—7.0	1848	61.1	2863	70.2
7.1—9.0	789	26.1	1023	25.1
9.1—11.0	271	8.9	165	4.0
11.1—13.0	77	2.5	19	0.5
Above 13.0	38	1.2	7	0.2

4.2. Fig. 2 illustrates the frequency distribution of heights of tops of cumulonimbus clouds around Gauhati Airport and gives also the number of *Cb* clouds falling in each height group in various months during the 24-month period of this study. The histogram (Fig. 2) also depicts the month by month variation in maximum heights reached by cloud cells. It is interesting to note that maximum number of *Cb* clouds occur over the Brahmaputra valley during the monsoon season, but the tallest clouds occur during pre-monsoon, mostly in April and May. The maximum top of the *Cb* cloud obtained in this study is 19.0 km in May.

TABLE 4

Frequency distribution of *Cb* cloud tops during different periods of the day in pre-monsoon and monsoon seasons

Period	Pre-monsoon		Monsoon	
	No. of cases	Frequency (%)	No. of cases	Frequency (%)
Early morning (0001-0400 IST)	410	13.6	456	11.1
Morning (0401—0800 IST)	313	10.3	498	12.4
Noon (0801—1200 IST)	388	12.8	679	16.6
Afternoon (1201—1600 IST)	748	24.8	1020	25.0
Evening (1601—2000 IST)	616	20.4	782	19.2
Night (2001-2400 IST)	547	18.1	642	15.7

4.3. Table 2 gives details of storms of different height groups forming in different periods of a day. It can be seen from Table 2 that maximum number of cumulonimbus clouds form during afternoon (1200 to 1600 IST). An analysis of Table 1 will show some interesting features while as many as 825 cases of cumulonimbus clouds were detected during the month of August in 1968, only 90 cases were found to occur in the same month in 1969. From the same table it can be seen that July and August have been the months of maximum storm formations.

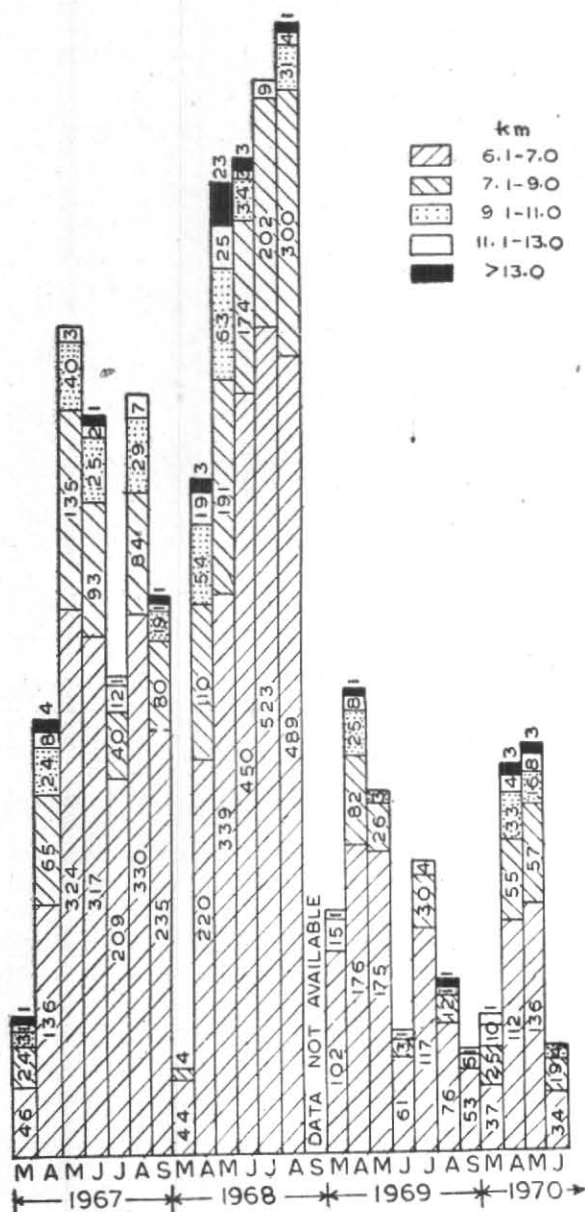


Fig. 2. Frequency distribution of heights of Cb tops around Gauhati Airport

4.4. Table 4 shows a clear picture of consolidated number and frequency of radar clouds during different periods of a day. A gradual change in frequency of Cb cloud formations will be seen from morning (0401-0800 IST) reaching a maximum during afternoon (1201-1600 IST)

and then a gradual step down of frequency with a minimum at the morning again. The fact, it seems, is special to the Brahmaputra valley as the same was not found by earlier workers at Delhi (Kulshrestha 1962) and at Calcutta (Bhattacharyya and De 1966).

5. Concluding remarks

5.1. It will be seen from this analysis that (1) During pre-monsoon season, about 87 per cent of cumulonimbus clouds mature below 9 km and only about 4 per cent grow above 11.0 km and (2) During monsoon season more than 95 per cent of cumulonimbus clouds mature below 9 km while only 0.7 per cent grow above 11.0 km.

5.2. It will be seen from Table 2 and Fig. 1 that over Brahmaputra valley cumulonimbus clouds always attain their maximum heights in the afternoon and evening, *i.e.*, between 1200 to 2000 IST. It can also be seen from Table 2 that maximum number of clouds also form in the afternoon (1200-1600 IST) in both the seasons. From Table 4 it will be seen that percentage frequency of formation of storms are nearly the same for both the seasons in the corresponding afternoon and evening.

5.3. Irrespective of the height intervals, the percentage frequency at any period of the day is comparable in both the seasons (pre-monsoon and monsoon).

5.4. Over Brahmaputra valley cumulonimbus cloud does not generally grow beyond 10 km particularly in monsoon although cloud tops reaching 14 to 15 km also are not uncommon. Cloud tops reaching as far as 19 km also have been recorded.

5.5. Maximum frequency of formation of cumulonimbus clouds is in the month of August.

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