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A radar study on the frequency of occurrence of cumulonimbus clouds around Delhi

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सार — सुरक्षित वायु परिवहन के लिए कपासी मेघों की परिघटना की बारंबारता के साथ-साथ उनके शीर्षों की ऊंचाई की ठीक जानकारी भी उपयुक्त है। जून 1958 से लेकर मई 1980 तक 22 वर्षों की अवधि के दौरान उच्च शक्ति वाली रेडार की सहायता से दिल्ली के आस-पास 100 कि. मी. के अंदर संवाही मेघों के एकत्रित आंकड़ों के आधार पर दिल्ली क्षेत्र में कपासी मेघों की परिघटना की बारंबारता का अध्ययन किया गया है। अध्ययन से पता चला है कि संवाही मेघों का 46 प्रतिशत कपासी मेघों के विकास के लक्षणों को प्रकट करते हैं। इनमें से 90 प्रतिशत मामलों में मेघ शीर्ष 12 कि. मी. तक सीमित रहे। केवल 1.6 प्रतिशत मामलों में ही मेघ शीर्ष क्षोभ मण्डलीय सीमा को भेद गये हैं। मेघ शीर्षों की अधिकतम ऊंचाई 20 कि. मी. पाई गई है। अध्ययन का विवरण प्रस्तुत है।

ABSTRACT. Precise knowledge of the frequency of occurrence of cumulonimbus clouds as well as heights of their tops is pertinent for safe air navigation. A study has, therefore, been made of the frequency of occurrence of cumulonimbus clouls in the Delhi region based in the data collected with the help of a high power radar, of convective clouds within 100 km around Delhi during the 22-year period, June 1958 to May 1980. The study has indicated that about 46 per cent of the convective clouds depict features of cumulonimbus development. Among these, in about 90 per cent cases, cloud tops have been limited to 12 km. In only 1.6 per cent cases, tops have penetrated the tropopause. The maximum cloud top height observed has been 20 km. Details of the study are presented.

1. Introduction

Cumulonimbus clouds are manifestation of great instability in the atmosphere. In India, several studies based on either debriefing reports from the jet airliners or meteorological reconnaissance flight observations or radar observations are available for different regions on this subject. In this paper, an attempt has been made to make further study on cumulonimbus clouds, in and around Delhi, using radar observations made during the period from June 1958 to May 1980. In the present investigation, a convective cloud-census within 100 km around Delhi for different months and seasons has been first prepared. Then the statistics of deep convective clouds (cumulonimbus clouds) has been obtained and the frequency distribution of the heights of their tops has been studied. A year has been broadly divided into four seasons, *viz.*, December to February (Winter), March to June (Pre-monsoon), July to September (Monsoon) and October to November (Post-monsoon) for the above study.

2. *Equipment* used and data collected

The study is based on hourly radar observations taken mainly from 1000 hrs to 1700 hrs (IST). A 3.2 cm Japanese radar of type NMD-451A has been used. The characteristics of the radar and the method of observations of the heights of precipitation echoes have been described by Ramana Murty *et al.* (1960). In any one observation, precipitation echoes observed around Delhi are picked up at random and the heights of their tops are measured.

All the convective echoes observed within a radius of 100 km around Delhi (28°37′N, 77°12′ E, 217 m MSL) have been considered. In all, a total number of 11,709 convective echoes have been investigated. Assuming that echoes extending beyond 6 km are representative of cumulonimbus clouds, it has been noted that as many as 5,331 echoes fell under the category of cumulonimbus.

3. Results and discussion

3.1. *Frequency of occurrence*

The percentage of convective clouds, which fell under the category of cumulonimbus is presented, monthwise, in Table 1. The corresponding percentages on seasonal basis are tabulated in Table 2.

TABLE 1

Echoes from convective clouds depicting the feature of cumulonimbus in different months

Months	No. of cumulonimbus clouds	No. of convective clouds	Percentage of convective clouds depicting the features of cumulonimbus
Jan	119	662	18.0
Feb	165	639	25.8
Mar	327	713	45.9
Apr	269	450	59.8
May	294	432	68.1
Jun	714	1,091	65.4
Jul	1,505	3,007	50.0
Aug	1,209	2,621	46.1
Sep	638	1,698	37.6
Oct	59	105	56.2
Nov	7	25	28.0
Dec	29	266	10.9
Annual	5,335	11,709	45.6

TABLE 2

Echoes of convective clouds depicting the feature of cumulonimbus in different seasons

Season	No. of cumulonimbus clouds	No. of convective clouds	Percentage of convective clouds depicting the features of cumulonimbus
Winter (Dec-Feb)	313	1,567	20.0
Pre-monsoon (Mar-Jun)	1,604	2,686	59.7
Monsoon (Jul-Sep)	3,352	7,326	45.8
Post-monsoon (Oct-Nov)	66	130	50.8

It may be seen (Table 1) that the percentage which showed cumulonimbus development was minimum in December (10.9 per cent) and maximum in May (68.1 per cent). Also, the cumulonimbus activity progressively increased from December to May. On seasonal basis (Table 2), the percentage showing cumulonimbus development was maximum during pre-monsoon (59.7 per cent) and minimum during winter (20.0 per cent). This feature is in conformity with what is expected on the consideration that atmospheric instability is maximum during pre-monsoon and minimum during winter. The variation was not conspicuous during monsoon and post-monsoon seasons. For the year as a whole, 45.6 per cent of convective clouds showed cumulonimbus development.

3.2. *Variation in height*

The echoes which have been categorised as cumulonimbus were classified into different height groups at 2 km height interval. The percentage frequency distribution of the heights of echo tops are given month-wise and seasonwise in Tables 3 and 4 respectively. All echoes whose tops extended beyond 16 km were included in a single class. The mean as well as the maximum height attained are also given in these tables.

The maximum frequency of cumulonimbus clouds has been noted in the height interval 6.1 to 8.0 km during each month (Table 3). During July, 14.4 per cent of the echoes representing cumulonimbus grew beyond 12 km. The frequencies of such clouds were marginally low during June and August (13.7 and 12.9 per cent respectively). Clouds with tops exceeding 12 km were not observed during January, November and December. They grew beyond 16 km (average tropopause level over this region) during the months May to October and their frequency of occurrence was maximum during July (2.5 per cent). The maximum height of their tops observed was 20.0 km. In all there were six such cases, out of which one was observed in June, two in July and three in August. However, such large height observed in June was towards the end of June.

Seasonwise analysis (Table 4) indicated that the frequency of occurrence of clouds with tops exceeding 12 km was minimum during winter and maximum during monsoon. The frequencies varied between 0.6 per cent to 12.6 per cent. Cloud tops exceeded 16 km in 1.1, 1.9 and 1.5 per cent cases during pre-monsoon, monsoon and post-monsoon seasons respectively. During winter, clouds with tops exceeding 14 km were not observed. The mean height of the cumulonimbus tops were minimum during winter season and maximum during monsoon season. The larger heights attained by them during monsoon compared to those during pre-monsoon may be attributed to the entrainment of relatively warmer environmental air in the monsoon season

TABLE 3

Percentage frequency distribution of cumulonimbus tops among different height intervals in different months

Month	Height (km)						Total No. of occasions	Percentage of annual	Maximum height (km)	Mean height (km)
	6.1 to 8.0	8.1 to 10.0	10.1 to 12.0	12.1 to 14.0	14.1 to 16.0	>16.0				
Jan	84.0	10.9	5.1	—	—	—	119	2.2	12.0	7.5
Feb	69.7	24.8	4.3	1.2	—	—	165	3.1	14.0	7.8
Mar	51.1	37.6	10.4	0.9	—	—	327	6.1	14.0	8.3
Apr	57.6	33.1	7.4	1.5	0.4	—	269	5.0	15.0	8.1
May	43.9	34.3	15.0	4.1	1.7	1.0	294	5.5	19.0	8.8
Jun	47.4	23.5	15.4	6.0	5.6	2.1	714	13.4	20.0	9.2
Jul	48.5	24.7	12.4	6.4	5.5	2.5	1,505	28.2	20.0	9.1
Aug	50.3	25.6	11.2	5.5	5.6	1.8	1,209	22.7	20.0	9.0
Sep	64.1	20.1	8.2	3.4	3.4	0.8	638	12.0	18.5	8.3
Oct	64.4	16.9	6.8	5.1	5.1	1.7	59	1.1	16.5	8.5
Nov	85.7	14.3	—	—	—	—	7	0.1	10.0	7.3
Dec	96.6	3.4	—	—	—	—	29	0.6	9.0	7.1
Annual	52.9	25.4	11.2	4.7	4.2	1.6	5,335	100	20.0	8.8

TABLE 4

Percentage frequency distribution of cumulonimbus tops among different height intervals in different seasons

Season	Height (km)						Total No. of occasions	Percentage of annual	Maximum height (km)	Mean height (km)
	6.1 to 8.0	8.1 to 10.0	10.1 to 12.0	12.1 to 14.0	14.1 to 16.0	>16.0				
Winter (Dec-Feb)	77.6	17.6	4.2	0.6	—	—	313	5.9	14.0	7.6
Pre-monsoon (Mar-Jun)	49.2	30.0	13.0	3.8	2.9	1.1	1,604	30.1	20.0	8.7
Monsoon (Jul-Sep)	52.1	24.1	11.2	5.5	5.2	1.9	3,352	62.8	20.0	8.9
Post-monsoon (Oct-Nov)	66.7	16.7	6.1	4.5	4.5	1.5	66	1.2	16.5	8.4

(Venkateswara Rao 1955). Also, maximum number of cumulonimbus clouds was observed during monsoon season (62.8 per cent of the annual) and minimum during post-monsoon season (1.2 per cent of the annual). The feature noticed is due to the fact that during monsoon, precipitation occurrence is frequent on account of heavy monsoon activity, whereas, during post-monsoon, it is occasional because, in this season,

precipitation occurrence is due to certain late monsoon depressions in October or early western disturbances in November.

For the year as a whole, it may be seen that in about 90 per cent of cumulonimbus clouds, tops were limited to a height of 12 km out of which in about 60 per cent cases cloud tops were below 8 km. In only 1.6 per cent cases cumulonimbus clouds grew beyond 16 km (average tropopause level over this region).

4. Conclusions

The study made has shown the following features :

(*i*) About 46 per cent of the convective clouds forming around Delhi grow into cumulonimbus.

(*ii*) Cumulonimbus clouds forming around Delhi mature and dissipate below 12 km in about 90 per cent cases. Only in 1.6 per cent cases they penetrate tropopause.

(*iii*) Maximum number of cumulonimbus clouds occur during the monsoon season (about 63 per cent of the annual). During the post-monsoon season, occurrence of such clouds is minimum (about 1 per cent of the annual).

(*iv*) Heights of the cumulonimbus cloud tops are largest during monsoon and least during winter.

(*v*) The maximum height of radar echo observed was 20 km.

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