Temporal variations of frequency of occurrence, horizontal size, height and aspect ratio of radar echoes from convective clouds around Delhi during monsoon season

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Temporal variations of frequency of occurrence, diameter \((D)\), height \((H)\) and aspect ratio \((H/D)\) of radar detected precipitation echoes from convective clouds in Delhi region during the monsoon season have been studied. The study is based on hourly radar observations of precipitation echoes from 2467 convective clouds made during the monsoon seasons of 3-year period, 1977-79. Radar observations were taken mainly between 1000 and 1700 IST (0430 and 1130 UTC). Frequency of occurrence of such precipitation echoes has been found to be more in afternoon and less in morning. Similar trend has been observed in the temporal variations of height and aspect ratio of precipitation echoes of these clouds. On the other hand, diameter of the echoes has been found to be maximum in the morning and minimum at noon. The study has also shown that the echo diameter has a linear relationship with its height. The relationship can be expressed by a regression equation, \(D = aH + b\), where \(a\) and \(b\) are the coefficients to describe the equation.

1 Introduction

With the advent of radar, a good deal of studies relating to the frequency of occurrence of convective clouds as well as their size and height distributions, fractal dimensions, vertical growth and decay rates and durations have been made in different regions of India\(^1\)\(^-\)\(^12\). However, very few studies have been made in respect of temporal variations of frequency of occurrence of convective clouds and some of these parameters, namely, horizontal diameter \((D)\), height \((H)\), and aspect ratio \((H/D)\). Knowledge of these aspects of convective clouds is very important in understanding the growth mechanism of such clouds. Kulshrestha\(^8\) and Sheshadri\(^13\) have studied the diurnal variation of heights of cumulonimbus clouds in Delhi region considering a limited number of cloud cases. Similar study has been made by Biswas and Gupta\(^1\) for Calcutta region. In this paper, temporal variation of the frequency of occurrence of radar detected precipitation echoes from convective clouds as well as the temporal variations of \(D, H\) and \(H/D\) of such clouds observed in Delhi region during the monsoon seasons (July-September) of three year period from 1977 to 1979 have been studied.

2 Data and method of analysis

The data used in the present study are based on hourly radar observations of precipitation echoes from convective clouds within 100 km around Delhi made during the 3-year period from 1977 to 1979. A X-band high power Japanese radar of type NMD-451A was used for this purpose. The characteristics of the radar set are given in Table 1. Two displays, namely, plan position indicator (PPI) and range elevation indicator (REI) of the radar set were used to make complete set of observations. Radar observations were mainly taken from 1000 to 1700 IST (0430 to 1130 UTC). On each occasion, the radar was first operated on PPI mode at low elevation angle (2.5°).

<table>
<thead>
<tr>
<th>Table 1 - Characteristics of the radar used</th>
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<tr>
<td>Wavelength</td>
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<td>Peak power transmitted</td>
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<td>Pulse length</td>
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<tr>
<td>Minimum detectable signal</td>
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<td>Pulse repetition frequency</td>
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<td>Horizontal and vertical beam width</td>
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and PPI photographs were taken to monitor the precipitation occurrences and their general features around Delhi. Then the heights of the precipitation echoes were measured on REI. From the data so collected, precipitation echoes from convective clouds were selected. A total number of 2467 convective echoes observed during the period under survey have been considered for the present study. It may be mentioned that the radar observations were taken at maximum receiver gain. As such, characteristic sizes of the precipitation echoes were not range dependent.

To study the temporal variations of convective clouds, total number of convective echoes which occurred in each hour during the period under survey and their mean diameter ($D$), mean height ($H$) and mean aspect ratio ($H/D$) in each hour were evaluated and each of these parameters was plotted against time. For the purpose of discussing the results, the observation time has been divided into four significant periods as follows: 1000-1200, morning; 1200-1400, noon; 1400-1600, afternoon; and 1600-1800, evening.

3 Results and discussion

3.1 Temporal variation of the frequency of occurrence of convective clouds

Figure 1 shows the temporal variation of frequency of occurrence of radar echoes of convective clouds. It may be seen from the figure that cloud formation is low in the morning, increasing progressively with the passage of day, becoming maximum at 1500 hrs, and then decreasing steadily. Similar trend has been observed by Kulshrestha$^8$ and Sheshadri$^9$. Maximum frequency of occurrence of convective clouds in the afternoon as seen is due to the strong thermal convection which sets in during the afternoon.

3.2 Temporal variation of mean diameter of convective clouds

Figure 2(a) shows the temporal variation of the mean diameter of the radar echoes of the convective clouds. It may be seen from the figure that the mean

![Fig. 1 - Temporal variation of frequency of occurrence of radar echoes from convective clouds around Delhi observed during monsoon seasons of 3-year period, 1977-79.](image1)

![Fig. 2 - Temporal variations of mean diameter ($D$), mean height ($H$) and mean aspect ratio ($H/D$) of radar echoes from convective clouds around Delhi observed during monsoon seasons of 3-year period, 1977-79.](image2)
diameter of the convective clouds is maximum in the morning at 1000 hrs, thereafter decreasing rapidly and becoming minimum at noon at 1300 hrs, registering increase again till 1500 hrs followed by slight decrease up to 1600 hrs and then sharp increase in the evening. The trend of the observed time dependence of diameters of the radar echoes of convective clouds appears to be somewhat inversely related to the degree of thermal convection in the atmosphere, which is less in the morning and evening and more during noon and afternoon. On the other hand, heights of the convective echoes appear to be directly related to the degree of thermal convection in the atmosphere.

3.3 Temporal variation of mean height of convective clouds

Figure 2(b) shows the temporal variation of the mean height of the radar echoes of the convective clouds. A reverse trend has been observed in the temporal variation of the mean height as compared to the temporal variation of the mean diameter. Mean height of the convective clouds is minimum in the morning at 1000 hrs. Then with the increase in the thermal convection during the course of the day, mean height of the clouds increases till noon (1300 hrs) and then, after showing a slight decreasing trend, it increases rapidly and reaches maximum in the afternoon at 1600 hrs. Thereafter, mean height decreases with the decrease of thermal convection in the evening. Similar trend has been observed by Kulshrestha and Sheshadri.

3.4 Temporal variation of mean aspect ratio of convective clouds

Temporal variation of the mean aspect ratio (H/D) of the radar echoes of the convective clouds has been found to have similar trend as that of mean height [Fig. 2(c)]. Mean aspect ratio is minimum in the morning at 1000 hrs. However, the two maxima observed at 1300 hrs and 1600 hrs are of more or less of the same value.

3.5 Relationship between heights of convective clouds and their diameters

To study the relationship between the heights of convective clouds and their diameters, mean diameters of the radar echoes of such clouds in different height groups, each of 1 km interval, were computed. Figure 3 shows the plot of echo diameter versus echo height. It may be seen from the figure that echo diameter has a linear relationship with its height. Equation of the line of best fit is given by

\[ D = 1.03H - 0.83 \]

The slope of the line of best fit (i.e. 1.03) suggests that on an average diameters of the convective clouds in Delhi region during the monsoon seasons have almost 1:1 ratio with their heights. It may be mentioned that the temporal variations of height and diameter show a reverse trend, whereas, in general, a linear relationship is observed between the two parameters.

It may also be mentioned here that as the radar observations were taken mainly from 1000 to 1700 hrs, temporal variations could not be studied for all the 24 h of the day. We are well aware of this limitation of our study. However, the present study at least reflects the variations of frequency of occurrence and other parameters of convective clouds during the daytime.

References


