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Climatology of radar echoes around Nagpur during summer monsoon

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ABSTRACT. Results of a climatological study of radar echoes around Nagpur for the monsoon months (June to September) based on data from 1960 to 1968 have been presented in this paper. Average distribution of echoes around Nagpur during the monsoon months have a broad common pattern with two maxima in sectors within diagonally opposite northeast and southwest quadrants and two minima in the remaining quadrants. Diurnal variation in the echo frequency in different sectors is not significant in July, August and September, whereas it is quite pronounced in June.

1. Introduction

Usefulness of radar climatological studies is being increasingly recognised in the present age for aviation purposes. Systematic studies of radar climatology began in India during the last decade. Climatological studies of radar echoes around some of the principal aviation centres, *viz.*, Delhi, Calcutta and Bombay have been made by Kulshrestha and Jain (1964, 1965), De and Rakshit (1961), Datar *et al.* (1964) respectively and around Madras by Rao *et al.* (1961). The present study makes a similar attempt for the area around Nagpur airport.

2. General climatology of Nagpur

Nagpur (21°09'N, 79°07'E) is situated at an altitude of 311 m a.s.l., about 250 km southeast of Satpura range of mountains. It is surrounded by small hills within 20-30 km. According to Köppens climatic classification, it has a tropical rainy climate with mild and dry winter. About 88 per cent of its annual normal rainfall of 113 cm falls during monsoon months (June to Sep.). During this period 6-7/8 of its sky remains covered with clouds. Among the monsoon months, June is the hottest with normal maximum temperature of 38°C. There is a sharp fall in the temperature as the monsoon advances.

3. Data collection and method of analysis

A 3-cm Decca 41 type weather radar has been in operation at Nagpur since 1959. The radar antenna is located at a height of 15 m above the ground. It bears the following characteristics :

Peak power — 25 KW, pulse length — 2·0 micro sec, P.R.F. — 200 pps, horizontal and vertical beam width 0·75° and 4·0° respectively, and maximum range is 150 n. miles.

Data for the monsoon months for 9 years (1960-1968) has been utilised for this study. The basic data for the present study consists of 7247 individual radarscope diagrams covering observations taken at different synoptic hours, *viz.*, 00, 03, 06, 09, 12, 15, 18 and 21 GMT. The total area covered by this study was about $2 \cdot 235 \times 10^5$ sq. km.

For the purpose of determining echo-frequencies, the Polar Diagram was arbitrarily divided into 12 sectors by a 30° radial line, *i.e.*, 0 30°, 30°-60°, etc. Each such sector was further sub divided into 3 equal distance ranges of 40 n. miles and the outmost fourth sector of 30 n. miles range. The echo frequency in a distance range of a sector was taken as one when it contained one or more echoes irrespective of its areal extent. Similarly in absence of echo, the frequency was taken as zero. The echo frequency in each of the distance ranges was added to give the total echo frequency for a particular sector. Needless to say, the total echo frequency for a particular sector for a specified observation cannot exceed 4. Echoes organising as a 'line-squall' or 'broken-line' and covering more than one sector have also been considered in the present study.

The results of the investigation have been discussed in the following paragraphs.

4. Discussion

4.1. *Diurnal variation*

Percentage frequency of occurrence of echoes in different sectors at different synoptic hours for the months of June, July, August and September are presented in Fig. 1.

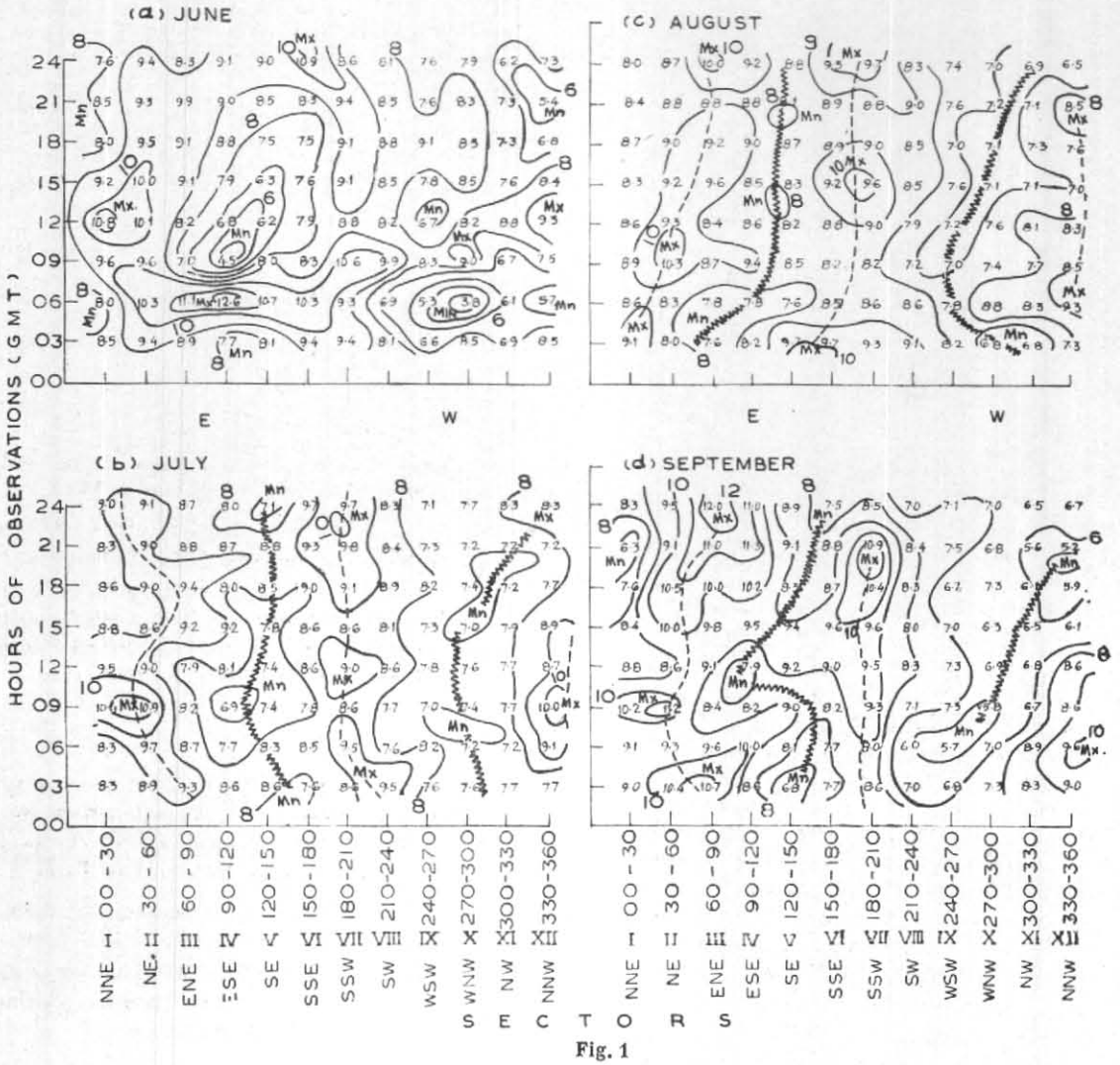

Fig. 1

Diurnal variation of percentage echo frequency in different sectors

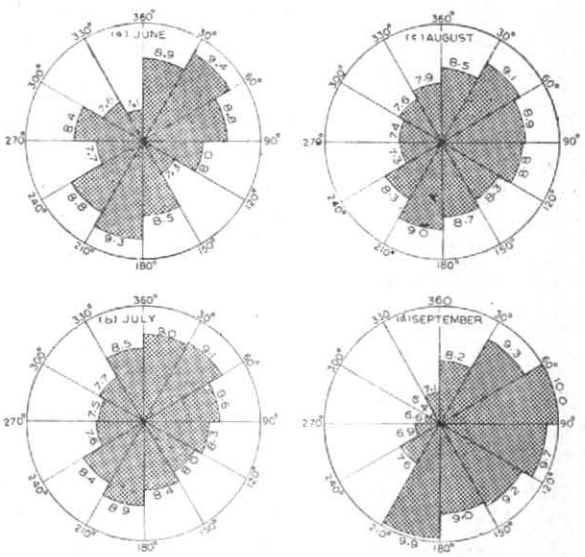

Fig. 2

Percentage echo frequency in different sectors (Figure in each sector represents mean echo frequency)

TABLE 1

Probability of occurrence of echo

	Time (GMT)							
	00	03	06	09	12	15	18	21
Jun	0·29	0·28	0·35	0·87	0·89	0·79	0·71	0·54
Jul	0·36	0·39	0·74	0·92	0·88	0·80	0·28	0·48
Aug	0·30	0·47	0·78	0·92	0·76	0·73	0·55	0·49
Sep	0·22	0·31	0·65	0·88	0·86	0·70	0·49	0·34

Compared to other monsoon months (July, August and September) concentration of iso-frequency lines is very conspicuous in the month of June, [Fig. 1 (a)]. Variation of echoes with time is also more pronounced in this month. The spatial distribution of echo frequency varies diurnally in this month from the lowest value of 3·8 at 03 GMT in the sector 270°—300° to the highest value of 12·6 at the same hour in the sector 090°—120°. It may be apropos to mention in this connection that the summer monsoon sets in the area around Nagpur by middle of June.

The iso-frequency lines for July, August and September have more or less a common pattern. The pattern for July shows two maxima and two minima persisting at all hours of day. A maximum occurs once in sectors lying between 330° to 090° (through 360°) and again in sectors covering 150° to 240°, situated more or less diagonally opposite to the first set. Similarly the minima occur in two sets of diagonally opposite sectors intervening the two maxima. Patterns for August and September are broadly identical to that of July with minor modifications. The spatial distribution of echo frequency in the months of July, August and September does not vary much diurnally as in June. The variation is roughly from 6·0 to 11·0. The diurnal changes in echo frequency in different sectors in these three months are not as significant as in June. Perhaps insolation does not play as pronounced a role in cloud formation during July, August and September around Nagpur as in June.

4.2. *Average spatial distribution*

Average percentage of echo distribution for the months June-September are depicted in Fig. 2. In June, the average percentage echo frequency exceed 7 in all sectors (Fig. 2a) with two maxima and two minima. A maximum in echo frequency (approx. 9·4 per cent.) occurs in the sectors 030°–060° and again in the sector 180°–210°. Similarly the minima of values approx. 7 per cent occur in sectors 330°-360° and 120°-150°.

In July, August and September (Figs. 2 b to 2 d), the pattern of June with two maxima and minima occuring more or less in diagonally opposite sectors is broadly maintained. The second minimum in the southeast quadrant is however not so marked in these months as in June.

4·3. *Probability of echo occurrence*

The probability of occurrence of an echo of even the smallest areal extent over the radarscope, when the radar was randomly put into operation at any of the synoptic hours have been worked out as below and presented in Table 1.

$$\text{Probability of echo at any hour} = \frac{\text{No. of occasions of detection of echo at that hour}}{\text{Total No. of occasions when radar was operated at that particular hour}}$$

It is worthwhile to note from Table 1 that upto 09 GMT during June, chances of echo formation are not significant, *i.e.*, are less than $\frac{1}{2}$. The probability increases suddenly after 09 GMT, becomes greater than $\frac{1}{2}$ and remain so even upto 21 GMT. In contrast, the probability during remaining monsoon months remain significant (*i.e.*, greater than $\frac{1}{2}$) between 06 and 15 GMT only and echoes mostly dissipate after that hour.

5. Conclusion

The following tentative conclusions can be drawn from the above study.

(*i*) The distribution of average echo frequency around Nagpur in all the monsoon months (June to September) has a broad common pattern with two maxima and two minima. The maxima occur in sectors lying broadly in the northeast and southwest quadrants and minima in the opposite quadrants. This finding is significant from the aviation point of view.

(*ii*) The diurnal variation of echo frequency in different sectors is more pronounced in June and less significant in other months.

(*iii*) Probability of occurrence of echoes is quite high between 06 and 15 GMT in July, August and September and between 09 and 21 GMT in June.

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