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Climatology of radar echoes around Nagpur during non-monsoon seasons

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ABSTRACT. Results of a climatological study of radar echoes around Nagpur for the non-monsoon months (October to May) based on data from 1960 to 1969 have been presented in this paper. The average distribution pattern reveal preponderance in echo formations in the eastern sectors. Echoes developing in northwest quadrant are believed to drift towards east during night or early morning hours.

1. Introduction

The climatolcgical study of distribution and other features of radar echoes around Nagpur for the monsoon season by the authors (1972) led to some interesting results. Greater persistency of radar echoes in the northwest and southeast quadrants in this season and general tendency of convective clouds to have tops around 6 km are some of the findings which are considered valuable from aviation point of view.

Development of convective clouds is observed around Nagpur in other seasons also. Considering the importance of Nagpur as a principal aviation centre in the country, it was felt appropriate to extend the study for the other seasons also so that an overall statistical picture of convective developments around Nagpur can be worked out and presented for the benefit of the aviators. With this view, the present study has been undertaken. The results obtained have been discussed and presented in this note. In this connection it may perhaps be stressed that Nagpur airport is served by a low power Decca 41 radar, whose ability, normally, to detect weak echoes (as is generally expected during non-monsoon months) particularly beyond 100 n. miles, should be limited. However, well defined echoes beyond 100 n. miles were observed in about 20 per cent of the total number of radarscope diagrams examined in this study. Thus, it appears that the performance of this radar beyond 100 n. miles, cannot be overlooked.

2. Data collection

For the purpose of the present study 10 years data (1960 -1969) for 9 months (October to May) were utilised. Analysis of 2190 individual radarscope diagrams of Nagpur obtained at regular 3-hourly observations (commencing from 00 GMT) has been made. It may be pointed out that during the period under investigation, there was hardly any occasion of prolonged breakdown of radar, in the non-monsoon months. Even occasions of short period breakdowns or decreased sensitivity in the performance, were very limited.

The weather radar at Nagpur was operated, regularly during the post monsoon and pre-monsoon periods. The winter season being a fair weather season, the observations were limited to cases of anticipated or actual bad weather situations over or around Nagpur.

With a view to determine the echo frequencies, the polar diagram was arbitrarily divided into 12 sectors, *viz.*, 0-30°, 30-60° etc. The radar range at Nagpur being about 150 nautical miles, each such sector was then further sub-divided into 3 equal distance range of 40 nautical miles each. The outermost range was, however, of 30 nautical miles.

The echo frequency in any distance range of a sector was taken as 1 when it contained one or more echoes, irrespective of its areal exent. In the absence of echo, the frequency was taken as zero. The sum of the frequencies in each of the distance ranges of a sector, has been taken as the total echo frequency for that sector. Obviously, the value of the total echo frequency is always 4. Echoes extending more than one sector as in line-squall, broken line etc have also been taken into account suitably in the study.

3. Diurnal variation

Sectorwise distribution of average echo frequency (in percentage) at 3-hourly intervals in the winter,

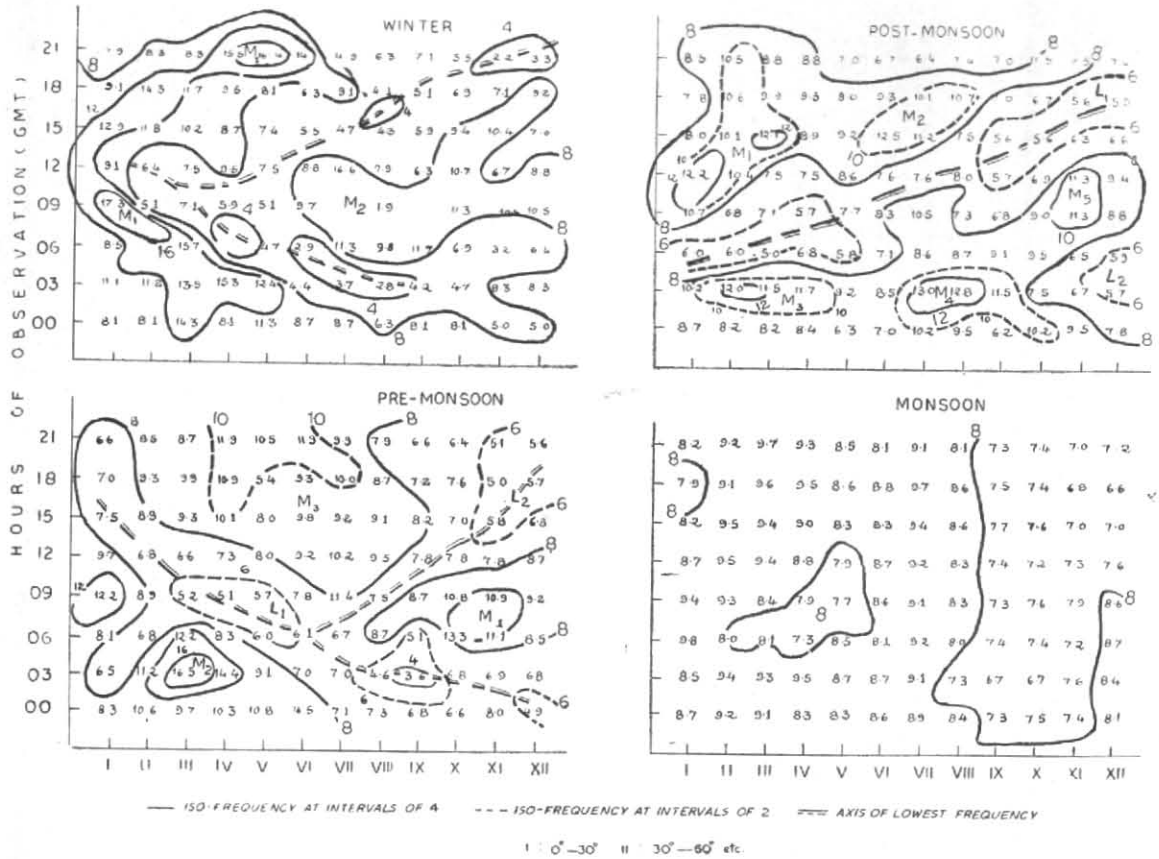

Fig. 1

Diurnal variation of echoes (sectorwise)

pre-monsoon and post monsoon seasons is presented in Fig. 1. The iso-frequency lines have been drawn at an interval of 4 per cent in the above figure. Isolines drawn at shorter intervals have been dotted.

The range of frequency variation is largest in the winter season (about 15 per cent — Fig. 1) and hence the gradient of iso-frequency lines is also greatest in this season. The range of variation decreases to about 13 per cent in the pre-monsoon season and to 8 per cent in the post monsoon season. The range of variation is practically negligible in the monsoon season (Fig. 1), being only about 3 per cent.

(a) *Winter season* — Persistence of high echo frequency (*see* run of 12 per cent echo frequency line — Fig. 1) in the northeast quadrant and adjoining sectors of southeast quadrant almost at all hours is a significant feature of this season. More rainfall also occurs in the northeast quadrant in this season than in other quadrants around Nagpur (*vide* Fig. 3).

The echo frequency waxes and wanes with time. During afternoon hours (09 to 15 GMT), the echo frequency increases in western quadrants (*see* region marked M_2 in Fig. 1) but diminished during night. It is envisaged that some of the echoes formed during afternoon hours in the western sectors slowly drift towards the eastern sectors with the zonal westerlies aloft in this season. The increases of echo frequency in the northeast quadrant particularly during night and early hours of morning is perhaps a consequence of the drift mentioned above.

(b) *Pre-monsoon season*—As in the winter season, the persistence of echoes of greater frequency (*see* M_2, Fig. 1) in the morning hours (00 to 06 GMT) in the northeast quadrant is observed in this season though not as conspicuously as in the winter season.

During the afternoon hours (06 to 12 GMT), a maximum in the echo frequency develops in the northwest quadrant and adjoining sectors (*see* M_1, Fig. 1) while in the northeast quadrant and adjoining sector the echo frequency decreases (*see* L_1, Fig. 1). The echo frequency though high during afternoon hours in the northwest quadrant, decreases during night (*see* L_2, Fig. 1). On the other hand, echo frequency increases in the northeast quadrant and the adjoining sec-

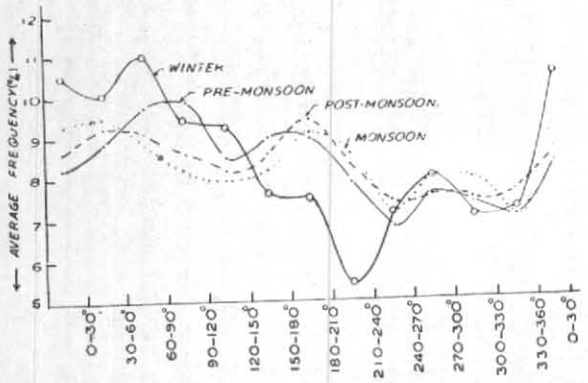

Fig. 2

Spatial echo distribution

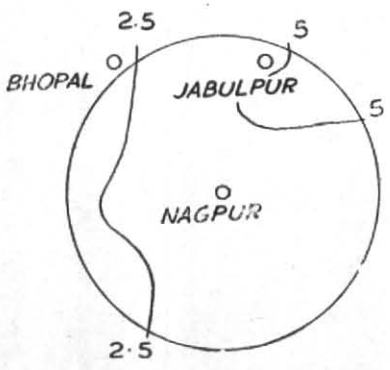

Fig. 3

Normal rainfall (mm) in winter

tors during the night and early morning hours. The increase is postulated to be due to slow drift of echoes from the western sectors with the basic zonal current aloft as in the winter season.

(c) *Post monsoon season* — Except in the northwest quadrant, the echo frequency develops and increases during the afternoon hours in other quadrants (*see* M_1, M_2 in Fig. 1). They tend to persist during the night and early morning hours of the next day (*see* M_3 and M_4 in Fig. 1).

In the northwest quadrant, though the echoes develop in the afternoon hours due to insolation etc (*see* M_5, Fig. 1) they mostly dissipate during night (*see* L_1 and L_2, Fig. 1). Some of the echoes in this quadrant formed during afternoon may also slowly drift to the eastern quadrant and contribute towards formation of echo maxima (M_3 and M_4) in the eastern sectors in the morning hours.

(d) *Monsoon season* — Echo formation is slightly less in the northwest quadrant and adjoining western sectors at all hours than in other quadrants.

4. Average spatial distribution

The average spatial distribution of the echoes for the 4 seasons have been depicted in Fig. 2.

In the pre-monsoon months, the frequency in the eastern half, particularly in 0 to 210° through 90° azimuth, exceed 8. Highest and lowest echo frequencies are observed in 90-120° and 210-240° sectors respectively. A secondary maxima and minima are also seen in 270-300° and 330-360° respectively. The average frequency during post monsoon is 8 in all sectors except in 240-270° and 330-360°. In this season also two maxima and two minima are seen, although they are not very prominent.

Higher echo frequencies, in winter season, are also confined to the eastern sectors, particularly within 0-150°, as in the pre-monsoon period. Similarly, two pairs of distinct and prominent maxima and minima are also observed.

The echo frequency in the monsoon months is mostly confined between 7 to 9, the eastern sector contributing much than the west. However, the peak frequency is observed in 180-210°.

Thus, broadly speaking, echoes are more numerous towards east of Nagpur than in the west, during non-monsoon months. The southwest quadrant is generally least crowded with radar echoes throughout the year. This is also corroborated by the distribution of average annual rainfall around Nagpur (Fig. 3).

5. Probability of echo occurrence

The probability of occurrence of an echo, even of smallest areal extent over the radarscope have been worked out as below and presented in Table 1.

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

During the pre-monsoon months, high probability (exceeding 30 per cent) of occurrence is first seen at 09 GMT persisting till 18 GMT and then gradually decreasing till the lowest value is attained at 06 GMT. In sharp contrast, the probability at any hour during post monsoon season, generally diminishes (*vis-a-vis* the probability at the same hour in pre-monsoon) and only during 09 and 12 GMT does it assume value exceeding 0·3. 00 GMT seems to be least favourable for echo formation both in post monsoon and winter months. Moreover, as compared to pre-monsoon, there is a sharp fall in the probability values, hour by hour, in winter.

TABLE 1

Probability of occurrence of echo (in percentage)

Season	Hours (GMT)							
	00	03	06	09	12	15	18	21
Pre-monsoon	12	14	9	45	50	38	30	22
Post monsoon	7	15	20	31	36	21	18	13
Winter	6	17	18	17	27	14	25	20

The highest probability during winter, though not very significant, occur at 12 GMT.

6. Conclusions

The following broad conclusions can be drawn from the present study—

(*i*) Echo in the radar range around Nagpur tends to appear more frequently in the eastern quadrant than in other quadrants in all the seasons other than monsoon.

(*ii*) The crowding of echoes is least in the southwest quadrant and greatest in the northeast quadrant in all the seasons other than monsoon.

(*iii*) The northwest quadrant seems to be a potential region where radar echoes form more frequently due to insolation. Echoes from this region appear to drift slowly and spread into the eastern quadrant during night and early morning hours.

(*iv*) The echo frequency distribution has the greatest range during the winter season. The range decreases during summer and post monsoon seasons and becomes least during monsoon.

(*v*) As compared to other seasons, the distribution of echoes during the monsoon season is practically uniform.

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