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Radar climatology of Madras airport and its neighbourhood

B. LAKSHMANASWAMY and V. SUNDARESA RAO

Regional Meteorological Centre Madras

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ABSTRACT. The areal distribution of radar precipitation echoes at Madras is presented seasonwise. A comparative study of echo distribution as related to normal rainfall pattern is given. The diurnal variation of the echoes and their development during different periods of a day over land and sea areas and also the monthly distribution of heights of echo tops are discussed. It is seen that the areal echo distribution and the normal rainfall pattern agree each other to a great extent and that there is a complete reversal of diurnal variation of echoes only over sea but not on land area from northeast monsoon to southwest monsoon and that the total echo frequency over land area is more than that over sea area in southwest monsoon season and *vice-versa* in northeast monsoon season.

1. Introduction

1·1. Weather radars have been in operation at all important airports in India. The importance of radar climatological studies has been emphasised by several authors (*see* Ref). A 3-cm (wave length) weather radar (Decca Type 41) was installed at Madras in 1959 and has been in operation since then. It has a maximum range of 250 nautical miles. It is well known that the attenuation on 3 cm wave length band is quite appreciable when there are intervening areas of heavy precipitation. Also this weather radar operates at a low peak power of 30 KW. It is, therefore, considered that the echoes occurring within 100 nautical miles represent a good estimate of their nature and covers an area of 41,680 square miles (statute).

1·2. Madras airport is situated on the east coast of India at Lat. 13°00'N and Long. 80°11'E with an average elevation of 16 m above mean sea level. Madras city is about 16 km to the northeast and the sea coast is about 8 km to the east. The topography of Madras and its neighbourhood is shown in Fig. 1.

1·3. Due to its proximity to the sea there is a good amount of maritime influence on its climate. Being in the tropics, Madras city and its neighbourhood have a warm moist climate which can be classified as "Tropical Maritime". This area is affected by southwest as well as northeast monsoons, the latter giving a major part of annual rainfall. The rainiest months are October and November and the least rainy months are February to April. The mean daily maximum temperature in a year ranges from 28° to 38°C and minimum temperature from 20° to 28°C.

2. Data collection and analysis

2·1. The data were collected from the recorded radar observation for sixty months from June 1964 to May 1969. After accounting for lack of data due to servicing, closure of radar watch, etc, there were in all 40,599 radar observations which provide the basic data for the study.

2·2. For the purpose of analysis, the area upto 100 nautical miles around the station was divided into 60 sectors; each sector bounded by a 30 degree radial line and 20 n.m. concentric range ring. Each radar observation at full hour GMT was plotted on the above polar diagram and the occurrences of precipitation echoes in each sector were combined for all the 24 hours in a day. The analysis was carried on to find out the total number of echoes in each sector for all the sixty months and average frequency in each sector was obtained seasonwise. Then the average percentage frequencies of occurrence of echoes to the total number of observations in a season were calculated. The areal distribution of the precipitation echoes thus obtained for different seasons was shown in Figs. 2 to 5.

2·3. To study the diurnal variation of echoes a day was divided into six periods. During a particular four-hour period, the total number of echoes occuring in different twelve sectors (0°-30°, 30°-60°, 60°-90° etc) was found out irrespective of the distance of echoes from the station for all the sixty months. Average percentage frequency of the precipitation echoes to the total number of observations for each four-hour period was calculated seasonwise. They were plotted on a polar diagram for the six periods of the day in each

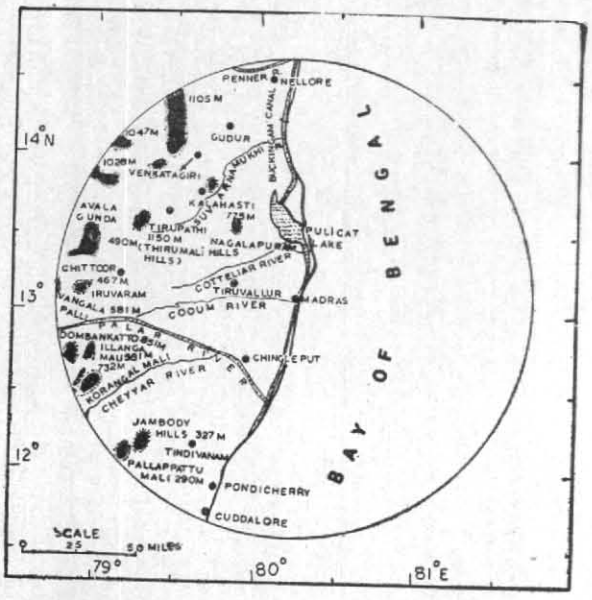


Fig. 1. Topography of Madras airport and its neighbourhood

TABLE 1

Rings in western sector (n. miles)	NE monsoon	Winter season	Hot weather season	SW monsoon	
0—20	75·0	9·0	15·0	75·0	62·5
20—40	49·0	9·0	12·5	45·0	34·5
40—60	9·0	4·5	13·0	35·0	26·5
60—80	13·0	3·6	14·25	19·0	11·5
80—100	3·0	1·95	11·25	6·75	3·2
Total	149·0	28·05	66·00	180·75	138·2*

*Echoes bounded by 40-cm isohyet.

season, each concentric circle representing the separation of four-hour period beginning with early morning from the centre of the polar diagram (Fig. 6). This depicts the areal distribution of the echoes in each four-hour period. The mid value of each period was plotted on the abscissa and the corresponding actual percentage frequency of echoes for each sector and for different seasons was plotted on the ordinate (Fig. 7). The trend of the curves depicts the diurnal variation of the precipitation echoes.

2.4. Isohyets were drawn seasonwise for the normal rainfall of the available stations within hundred nautical miles around Madras. The normal rainfall pattern was superimposed correspondingly on the figures depicting the areal distribution of precipitation echoes (Figs. 2 to 5). For the purpose of comparison of areal distribution of echoes with rainfall pattern the total echo frequency was found out between each ring (by taking mid value of the ranges) and is given in Table 1.

2.5. To study the monthly distribution of heights of echo tops, data were collected for the above period for the tops of echoes which reach 5 km or more. The persistence of a particular echo top was counted as one occasion. The echo tops were divided into three categories. The average echo tops in each month were shown in the histogram in Fig. 8. The figures in the histograms represent the average number of echo tops.

3. Areal distribution

3.1. A close examination of Figs. 2 to 5 shows :

(*a*) The highest frequency in any season does not exceed 15 per cent in any of the sixty sectors. This means that the maximum chances that a particular vulnerable sector being filled by a radar echo in any observation is of the order of 15 per cent only.

(*b*) The maximum percentage frequency occurs in northeast and southwest monsoon seasons. The minimum frequency whose range is as low as 0·10 to 0·50 per cent occurs in winter season.

(*c*) The maximum percentage frequency occurs around the station for both monsoon seasons. But the areal extent of these echoes is more in northeast monsoon than in southwest monsoon season.

(*d*) The entire northwestern sector has more number of echoes compared to any other quadrant in all the seasons.

(*e*) The total echo frequency over land is more in southwest monsoon than in northeast monsoon (Table 1).

The areal distribution of precipitation echoes seasonwise, starting from northeast monsoon for Madras, is as follows.

3.2. *Northeast monsoon season (October to December)*

(*i*) There is a gradual decrease of echoes from the station towards west. It may be because the echoes which approach the station encounter land, precipitate, decrease in intensity and dissipate as they move away westwards from the station.

(*ii*) The total frequency put together in the eastern half is more than that in the western half. The maximum frequency occurs upto forty miles to the east of the station whereas it occurs only

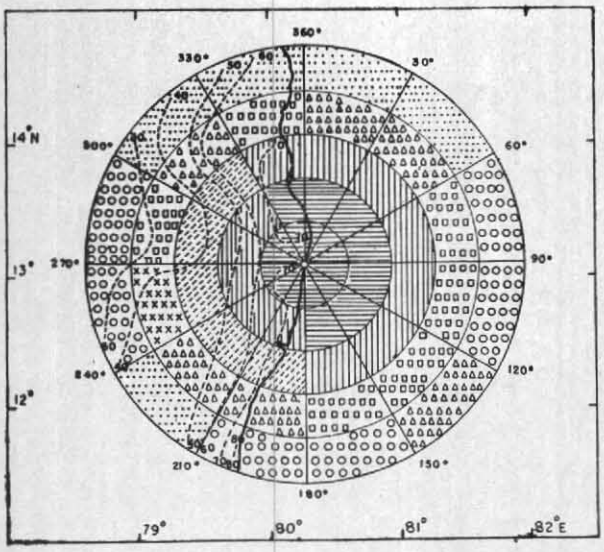


Fig. 2. Northeast monsoon season

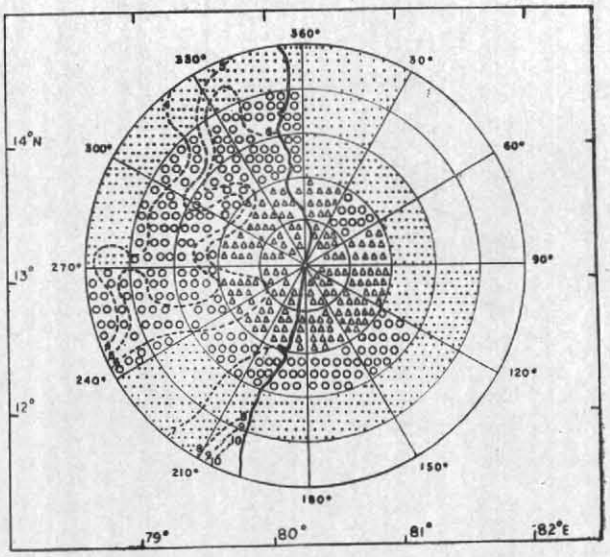


Fig. 3. Winter season

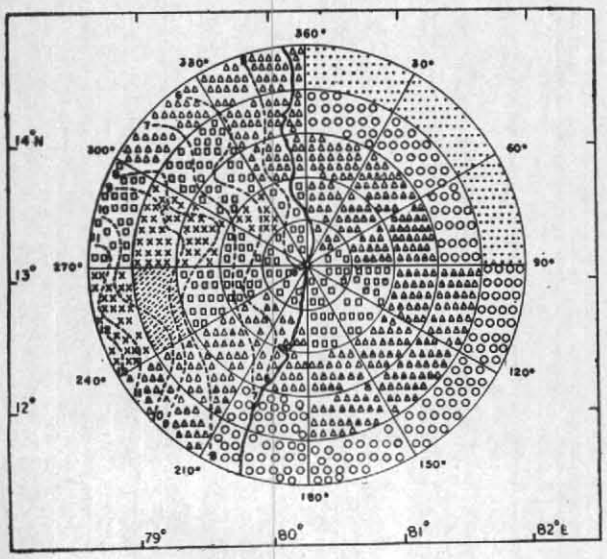


Fig. 4. Hot weather seaon

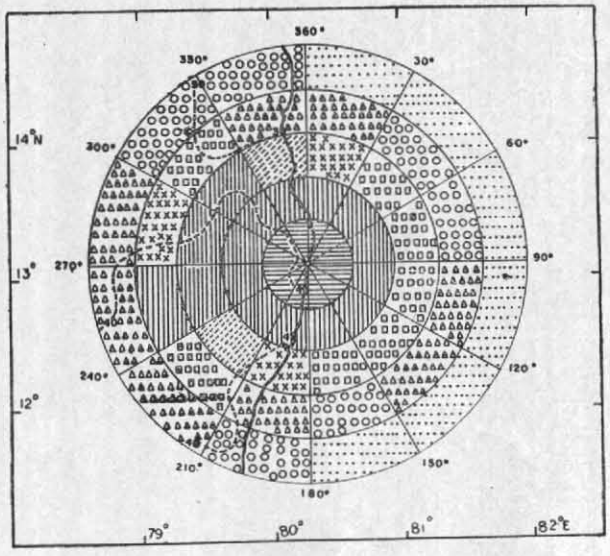


Fig. 5. Southwest monsoon season

Areal distribution of precipitation echoes (per cent) and normal rainfall patterns

upto twenty miles to the west. This larger frequency to the east is probably due to the presence of low pressure systems and their approach towards the station from east.

(*iii*) There is a greater frequency in the sector bounded by 330° and 360° radial lines than any other 30° sector in the western half.

(*iv*) It will be seen from Fig. 2 that the values of isohyets decrease westwards. This confirms the areal distribution of precipitation echoes in the western half in northeast monsoon season (Table 1.).

3.3. *Winter season (January to March)*

(*i*) The maximum frequency for this season is between 1·00 to 2·00 per cent only, *i.e.*, the chance of a sector being filled by precipitation echoes is very poor. According to the study by Rao *et al.* (1971) Madras is free from thunderstorm activity in January and February. In March the activity is low (the average monthly incidence of

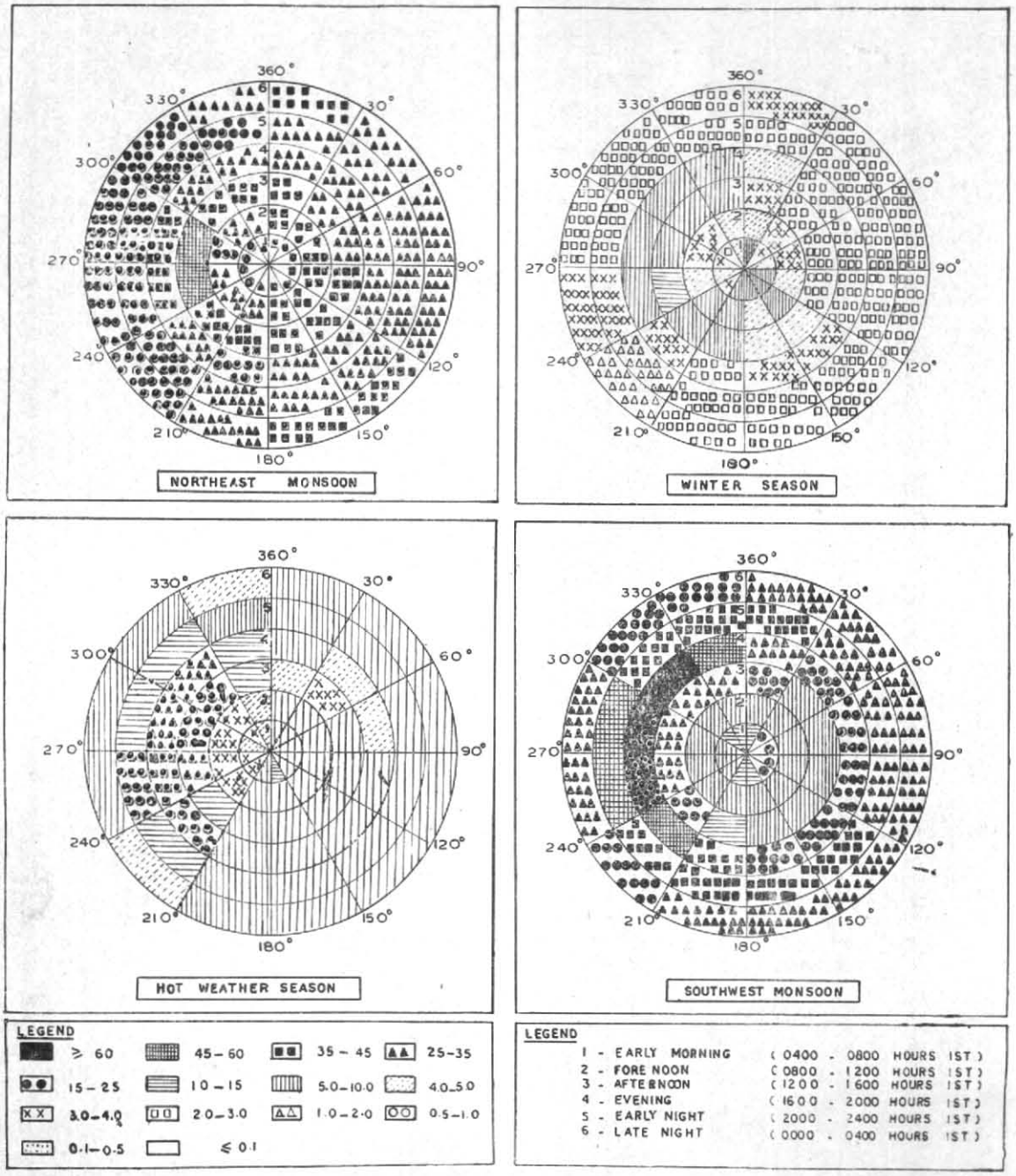


Fig. 6

Areal distribution of diurnal variation of precipitation echoes (per cent)

thunderstorm is 1·1 only). This supports the poor occurrence of precipitation echoes in the season.

(*ii*) The highest percentage frequency for this season is uniformly distributed around the station within a radius of 40 n.m. except for a small sector bounded by 30° and 60° radial lines and 20 and 40 n. mile-rings. This uniform distribution may be due to lack of any weather system moving across the station in this season.

(*iii*) It will be seen that the precipitation echoes occur in the entire northwest quadrant compared to any other quadrant of the station obviously due to orography.

(*iv*) The decrease of normal rainfall outwards the station confirms the decrease of precipitation echoes in the same direction. The higher amount of rainfall in SSE sector between 60 and 100 n.m.

is not, however, brought out by the areal distribution of precipitation echoes.

3.4. *Hot weather season (April to May)*

(*i*) The highest frequency for this season ranging from 4 to 5 per cent occurs only in a small area bounded by 60 and 80 n. miles rings and 240° and 270° radial lines.

(*ii*) The total number of echoes put together is greater in the area bounded by 240° and 330° radial lines than any other equal area in any other quadrant.

(*iii*) It will be seen from the normal rainfall pattern for hot weather season that the area between 240° and 330° radial lines experiences much more rainfall than any other equal area and the rainfall amount decreases towards the station. This is almost in conformity with the areal distribution of precipitation echoes in this season.

3.5. *Southwest monsoon (June to September)*

(*i*) The highest frequency of the echoes occurs uniformly within an area of 20 n. miles around the station, but the next higher frequency extends more in area in the west than in the east.

(*ii*) As in hot weather season the total frequency put together between 240° and 330° radial line is more than any other equal area in other quadrants.

(*iii*) The normal rainfall pattern in southwest monsoon season around Madras shows that a larger amount occurs in southwest sector and extends upto 300° radial lines. A look at the areal distribution and the table shows that the southwest sector has more number of echoes and extends upto 330° radial lines.

(*iv*) It will be seen that the total percentage frequency in the western half, *i.e.*, over land is more than the total frequency in the eastern half. This is in contrast with the areal distribution of echoes in the northeast monsoon season.

4. Diurnal variation of precipitation echoes

4.1. The areal distribution of the echoes in different periods of the day is shown as a polar diagram for different seasons (Fig. 6). The highest precipitation echo frequency of 60 per cent or more occurs in the evening during southwest monsoon between 240° and 330° radial lines. The minimum frequency of less than 2 per cent occurs in winter season between 210° and 240° radial lines.

4.2. *Northeast monsoon season* (Fig. 7a)

(*i*) It will be seen from the curves that over sea area the echo frequency gradually increases from evening (1800 IST) through night, reaches a maximum in the forenoon (1000 IST) and gradually decreases to a minimum in the evening. The occurrence of maximum sea surface temperature in October (Rama Ssstry 1963) and the lower air temperature (Williams 1963) suggest the possible supply of energy from the sea for convective clouds to build up. The coastal stations are affected due to the westward movement of the echoes. It is also observed at Madras that rainfall occurs in the morning hours.

(*ii*) Over land area the echo frequency increases from early morning, reaches maximum in the afternoon (around 1400 IST) and decreases gradually till the end of late night.

(*iii*) The diurnal variation of echoes over land follows the same trend in all the sectors though their peak values differ from one sector to the other.

4·3. *Winter season* (Fig. 7b)

(*i*) The maximum precipitation echo frequency over land area occurs in the same period as in previous season in all sectors (except the sector between 180° and 210°) with different percentage frequencies.

(*ii*) The echo distribution over sea area is not as symmetrical as in northeast monsoon season; but the maximum frequency in all sectors is shifted four hours earlier (0600 IST) than the one in northeast monsoon season.

4.4. *Hot weather season* (Fig. 7c)

(*i*) The maximum echo frequency in all the sectors over land shifts by four hours from the previous season and occurs around 1800 IST.

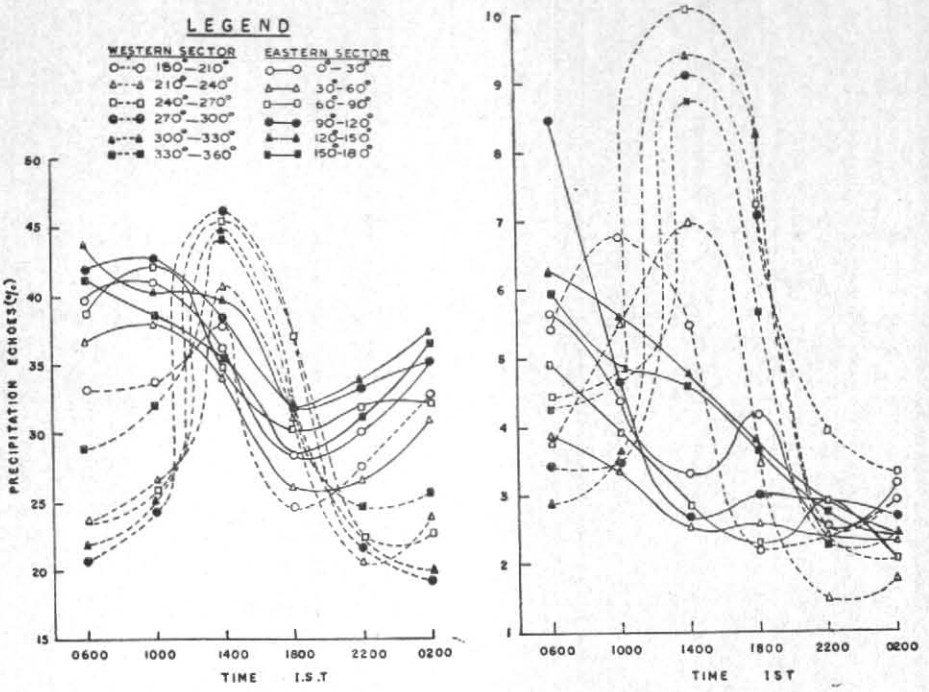
(*ii*) There is little change in the diurnal variation of echoes over sea.

4.5. *Southwest monsoon season* (Fig. 7d)

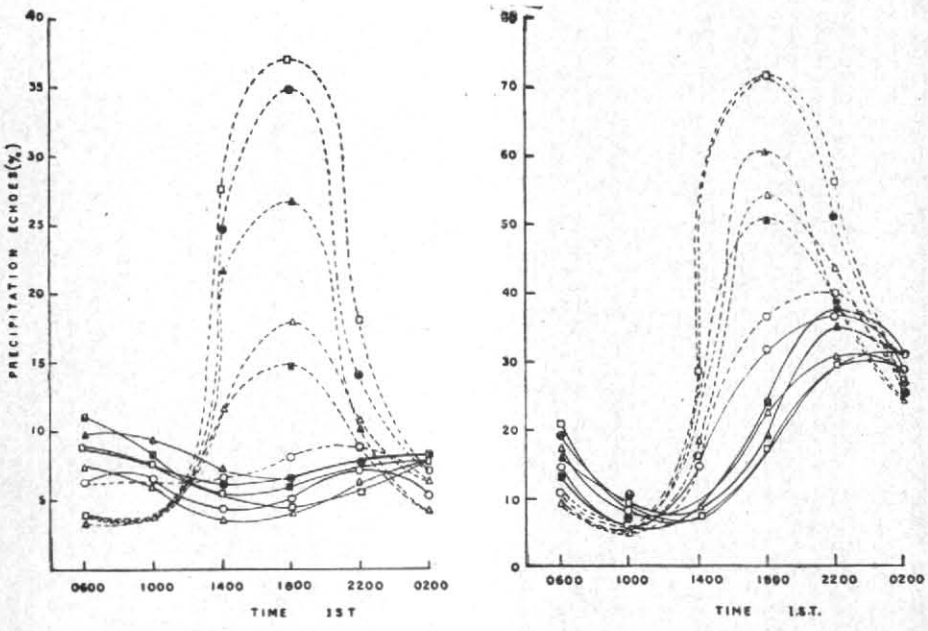
(*i*) In this season the echoes over land start increasing around 1000 IST, grow rapidly around 1400 IST, reach maximum around 1800 IST and gradually decrease during night.

(*ii*) Over sea area the diurnal variation of the echoes is a complete reversal to that in northeast monsoon season. The minimum occurs around 1000 IST and maximum around 2200 IST. The causes for this reversal of diurnal echo frequency need investigation.

(*iii*) The ranges in percentage frequency of occurrence of maximum echoes are different in



(*a*) Northeast monsoon season (*b*) Winter season



(*c*) Hot weather season (*d*) Southwest monsoon season

Fig. 7. Diurnal variation of echoes

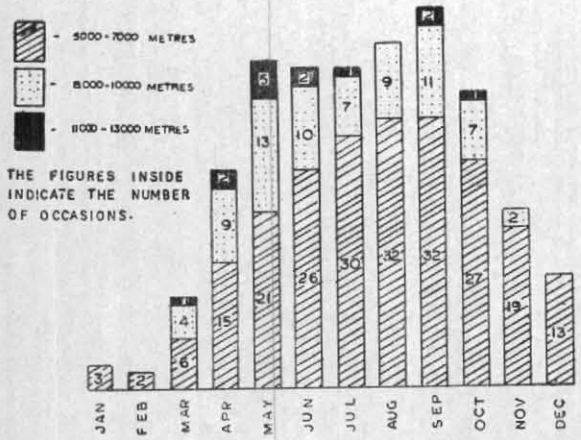


Fig. 8

Monthly distribution of heights of echo tops

different sectors over land whereas they are almost same in all the sectors over sea.

5. Monthly distribution of heights of echo tops

(*i*) It will be seen from Fig. 8 that the total number of echoes (5 km and above) increases gradually from March, reaches a maximum in August and September and gradually decreases till February.

(*ii*) The maximum number of echoes of the highest range (11-13 km) occurs in May.

(*iii*) There are no echoes whose tops are higher than 7 km during January and February and the average monthly incidence in January and February are only 3 and 2 respectively.

(*iv*) The total number of echo tops ranging from 5-7 km in southwest monsoon season is greater than the combined total of the echoes of the same range in the remaining seasons of the year.

6. Conclusions

1. The most vulnerable area for echo development in all the seasons is situated in the northwest quadrant and particularly in the area between 240° and 330° radial lines.

2. The total echo frequency over land area is more than that over sea area in southwest monsoon season and *vice-versa* in northeast monsoon season.

3. The areal echo distribution and the normal rainfall pattern agree with each other to a great extent.

4. The maximum echo frequency over land occurs around 1400 IST in northeast monsoon and winter season and shifts by four hours to 1800 IST in hot weather and southwest monsoon seasons.

5. There is a complete reversal of diurnal variation of echoes over sea from northeast monsoon to southwest monsoon.

6. The probability for the occurrence of echo tops reaching beyond 11 km is maximum in the month of May and no echoes beyond 7 km occur during January and February.

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