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On some aspects of distribution of meso-scale systems in Madhya Maharashtra and Marathwada during monsoon season

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सार — भारतीय क्षेत्र में दक्षिण-पश्चिम मानसून के दौरान विस्तृत वर्षा वाले क्षेत्र में कुछ छोटे-छोटे भारी वर्षा के क्षेत्र पाये जाते हैं। यह भारी वर्षा वाले क्षेत्र सूक्ष्म-माप प्रणालियों के केन्द्र होते है। यह क्षेत्र मध्य मापक्रम प्रणालियों के कारण बनते हैं जो स्वयं दीर्घ मापक्रम मौसम प्रणालियों में समाहित रहते है। प्रस्तुत अध्ययन में मानसून के मौसम में मध्य महाराष्ट्र तथा मराठवाडा में ऐसी मध्य मापक्रम प्रणालियों के विस्तार और उनके बंटन को ज्ञात करने का प्रयास किया गया है।

अलग-अलग दूरी पर स्थित दो स्टेशनों पर एक जैसी वर्षा होने या न होने की प्रायिकता का पता करने के लिये आकस्मिकता सूचकांक (आ.सू.) तकनीक का प्रयोग किया गया है। आ. सू. की दूरी के साथ होने वाले परिवर्तन से दीर्घ मापक्रम प्रणालियों में समाहित मध्य मापक्रम प्रणालियों के बंटन का संकेत मिलता है। इस तकनीक से एक ही आ. सू. वाले स्टेशनों पर एक जैसी वर्षा होने की यादृच्छिक सम्भावना नहीं रहती।

ABSTRACT. The pockets of heavy rainfall in a widespread rainfall system during the southwest monsoon period in the Indian region are the centres of meso-scale systems. Contingency index technique is applied to determine the diameters of such systems and their distribution over Madhya Maharashtra and Marathwada sub-divisions of Maharashtra during the monsoon period.

The technique determines the probability or otherwise of occurrence of rainfall of similar intensity at pairs of stations at different distances. The variation of CI with distance gives an indication of distribution of meso-scale cloud systems embedded in macro-scale systems. The method eliminates the random chance of occurrence of similar type of precipitation over stations having the same CI.

1. Introduction

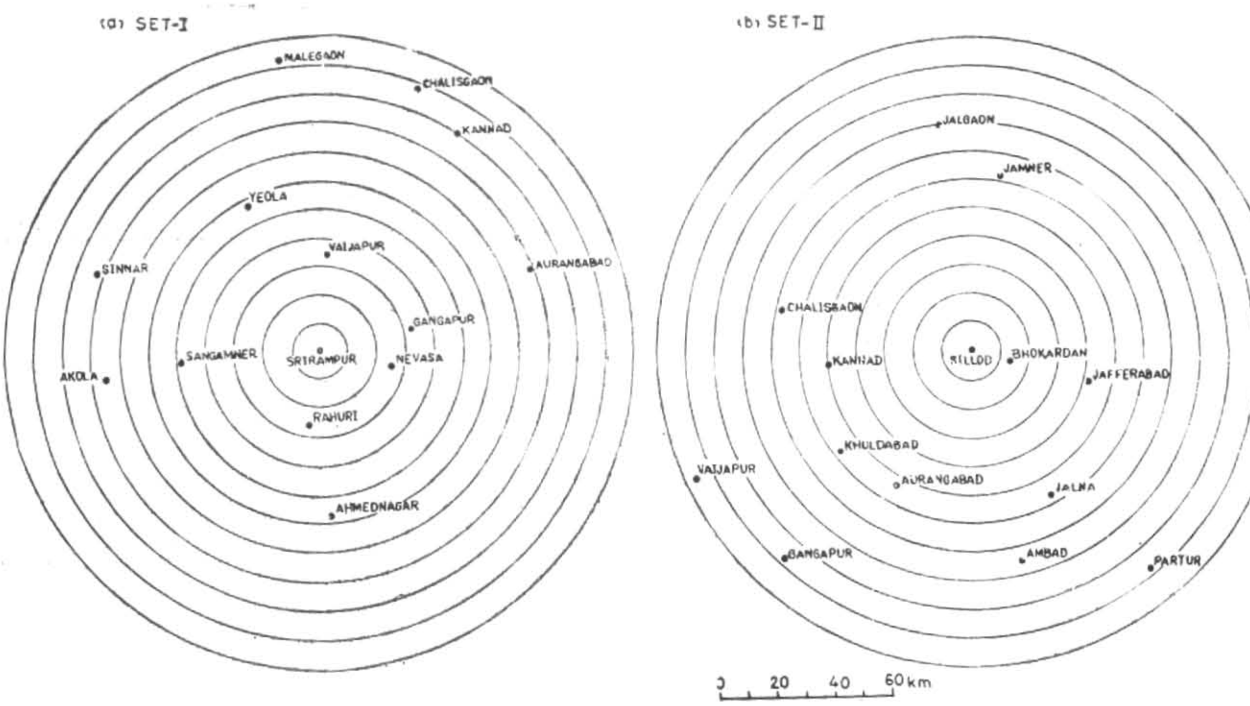
Earlier observations by a number of meteorologists established the existence of vertical motions with scales of the order of 10^3 km and it was recognised that weather associated with these cyclones and anticyclones could explain to a large extent the variance of meteorological parameters which occur on the scale of several days. The spacing of cities in which man lived and observed the weather was nearly ideal for resolving the structure of these vortices and such scales were termed as 'synoptic scale'. Subsequently, radar and weather satellites have revealed considerable spatial variability on a scale larger than cumulus cloud but smaller than synoptic. Observations of rainfall in a closer network of rain reporting stations show a variability in the rainfall amounts at all these stations although these are located in a much smaller area than that of the synoptic scale. This meso-scale distribution is the feature of all synoptic disturbances.

A study of data of the raingauge stations used in this study shows that on some days almost all stations report rain while on other days only a few have rain. The locations of these stations in the area of Madhya Maharashtra and Marathwada to which this study pertains are shown in Figs. 1(a&b).

In the Indian sub-continent many researchers have shown the existence of areas of convective activity (meso-scale systems) embedded in the macro-scale systems. Investigations undertaken under the programme 'Exercise Storm Exchange, 1973' have shown that monsoon depressions have small meso-scale circulations embedded in them which, perhaps, cause locally heavy rains. Small vortices (sometimes hardly 100 km or so in length), which form off the west coast of India in the monsoon season cause very heavy rainfall locally. Such meso-scale systems of short life period are important from forecasting point of view, particularly where accurate forecast for short periods of 1 to 3 hours over limited area is needed.

Many meteorologists have tried to work out the dimensions of these meso-scale systems embedded in a larger scale system. Billa and Raj (1967) used a triangle of recording raingauges near Pune to measure the dimensions of five meso-scale rain systems during summer of 1964. They found the median radius as 55 km.

In this paper an attempt is made to determine the dimensions of the meso-scale systems during the monsoon period in the areas of Madhya-Maharashtra and Marathwada by using Contingency Index Technique.



Figs. 1(a & b). Raingauge stations : (a) set I and (b) set II

2. Area selected for study and data used and synoptic situation

2.1. *Area of study and data used*

The areas in Madhya Maharashtra and Marathwada are selected in such a way that the effect of orography due to Western Ghats is minimised to a great extent. Two separate areas in the districts of Aurangabad, Ahmednagar, Nasik, Jalgaon and Jalna are selected for study. Rainfall data of the departmental (I.M.D.) and non-departmental including the State raingauge stations during the months of June to September (monsoon months) for the years 1976 to 1979 and for 1983 are utilised in the study. The situations selected for the study are those when there was widespread rainfall in the areas under study.

2.2. *Synoptic systems during monsoon period over Madhya Maharashtra and Marathwada*

The southwest monsoon normally covers the entire Peninsula during the second week of June and this is the wettest period of the year in Madhya Maharashtra and Marathwada. About 80% of annual rainfall occurs in this season. From July to August, there is a general decrease in the rainfall and in September, there is again an increase. As such two maxima of rainfall are noticed, one in the earlier half of the monsoon and the other towards the end of monsoon.

During the peak of monsoon, *i.e.*, in the months of July and August, Madhya Maharashtra and Marathwada may get heavy to very heavy rain in association with the movement of low pressure areas and depressions when these sub-divisions lie in the southwest sector of the disturbance. However, such occasions may be only a few in number in north Madhya Maharashtra and Marathwada. The other synoptic systems mentioned in the subsequent para may produce increased monsoon activity, but do not normally cause heavy and very heavy rainfall. However, towards the end of the monsoon season, these areas are liable to have very heavy rains, in association with the movement of the systems across the north or central Peninsula.

The synoptic situations which strengthen the monsoon activity over Madhya Maharashtra and Marathwada can be summed up as follows :

(*i*) Monsoon depressions and low pressure areas from the Bay.

(*ii*) Well marked seasonal monsoon trough in a southerly position.

(*iii*) A cyclonic circulation/low pressure system (700-500 mb) in the Bay of Bengal and another in the Arabian Sea with a trough connecting them running across the Peninsula.

(*iv*) Upper air cyclonic circulation over the Peninsula.

(*v*) North-south oriented trough in the monsoon westerlies.

The present study is a composite study for rainfall regimes caused by all the above mentioned systems as the rainfall data used is not segregated for each of the systems separately.

In each of the two selected areas raingauge stations in circular areas of radius 100 km are picked up for study. The raingauge stations are selected in all the directions radially outward from the centre of the circles (Figs. 1 a&b).

3. Methodology

Henry and Griffith (1963) developed a technique for studying the areal distribution of daily rainfall by using a contingency index found between pairs of stations in the area under study. Rainbird (1968) also used this technique to study the areal distribution of rainfall

TABLE 1

Schematic contingency table

Rainfall at station 'B'	Rainfall at station 'A' 0	<20	>20	Total
0	a_1	a_2	a_3	x_1
<20	a_4	a_5	a_6	x_2
>20	a_7	a_8	a_9	x_3
Total	y_1	y_2	y_3	T

where,

a_1 : No. of days when both the stations A & B have no rainfall.
a_2 : No. of days when station A has rainfall equal or less than 20 mm and station B does not have any rainfall.
a_3 : No. of days when station A has rainfall > 20 mm and station B has no rainfall. ....
a_5 : No. of days when both A and B have rainfall equal or less than 20 mm, and so on.

$x_1 = a_1 + a_2 + a_3$ $\quad y_1 = a_1 + a_4 + a_7$
$x_2 = a_4 + a_5 + a_6$ $\quad y_2 = a_2 + a_5 + a_8$
$x_3 = a_7 + a_8 + a_9$ $\quad y_3 = a_3 + a_6 + a_9$

and T is the total number of days.

TABLE 2

Rainfall at Jalna	Rainfall at Sillod 0	<20	>20	Total
0	70	44	7	121
<20	26	54	10	90
>20	5	26	15	46
Total	101	124	32	257

CI=0.26, Distance between the stations=57.5 km.

over Sesan sub-basin off the *Mekong* river, in three classes of summer disturbances, low level cyclones, sub-tropical cyclones and trough lines, and all rain regime. With the same technique Henry (1974) studied the areal distribution of the meso-scale systems (rainstorms). (defined to deposit 10 mm of rain in a day at one place) over southeast Asia, Columbia, Panama and Costa-Rica. In this study also the contingency index technique has been used to study the dimensions and the distribution of the meso-scale systems embedded in the widespread monsoon rainfall regime in the Madhya Maharashtra and Marathwada sub-divisions of Maharashtra.

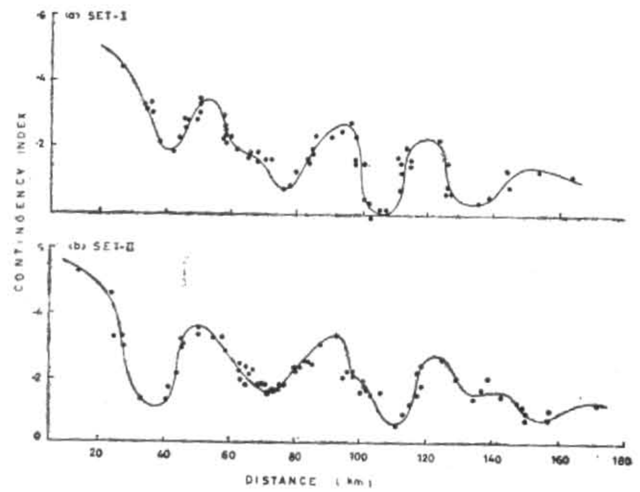
3.1. *Contingency index*

Contingency index technique is applied to relate the similar intensity of rainfall with distance. Brier and Allen (1951) have suggested a 3×3 contingency table as the best method of relating the data.

For constructing the contingency tables daily rainfall data for the period and area under consideration was distributed under three-class intervals, *i.e.*, $0 \leqslant 20$ mm and > 20 mm. The scheme of distribution of the rainfall under class intervals and the method of calculation of the contingency index is given in Table 1.

The random chance (b_1) that both the stations A and B have no rainfall is given by $b_1=(x_1y_1)/T$. Similarly, random chances b_5 and b_9 corresponding to a_5 and a_9 are given by :

$$b_5=x_2y_2/T \text{ and } b_9=x_3y_3/T$$



Figs. 2(a & b). Contingency index-distance curves : (a) set I and (b) set II

The contingency index is given by the relation,

$$\text{CI} = \frac{(a_1 + a_5 + a_9) - (b_1 + b_5 + b_9)}{T - (b_1 + b_5 + b_9)}$$

This value of contingency index represents that both stations A and B have rainfall in the same class of interval. The factor $(b_1+b_5+b_9)$ represents the random chance of occurrence of precipitation in the same class interval at both stations A and B. While calculating the contingency index this factor is eliminated. The values of CI, computed from the above table can have values ranging from +1 to −1. The value +1 will show the complete correspondence of rainfall amounts at the two stations in question, while −1 will indicate the chance of occurrence of the same category of rain less than the random chance. The value 0 represents no relationship between the stations.

The contingency indices are calculated for pair of stations for the two areas separately.

A sample contingency table prepared from the rainfall of the stations 'Sillod' and 'Jalna' is given in Table 2.

The rainfall data for all the stations in this area are available on 257 days during this period.

The values of class intervals were selected after trying for other class intervals also. The other values did not give better resolution between the maximum and minimum values of the contingency indices.

3.2. *Composite CI — Distance curve*

A graph between CI and distance is plotted for the sets of observations and a curve of best fitting by observation is drawn. These curves are shown in Figs. 2(a&b) . It is seen from the curves that the first minima lies between 35 & 40 km and then the maxima is obtained at 50-55 km. The higher values of CIs indicate a closer correspondence in the intensity of rainfall while the lower values are indication of little or no correspondence. Thus, the minima demarcate the boundary of one meso-scale system, which in this case appear between 35 & 40 km. After the first minima the values of CI increase again with distance and attain a maximum value at a distance of 50-55 km. This is the centre of another meso-scale system which is bounded by two minima on either side.

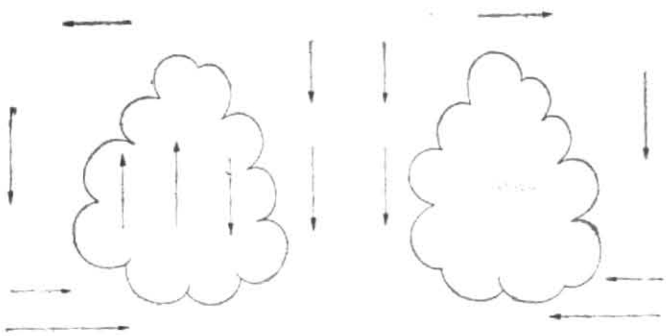


Fig. 3. Formation of convective system — Meso-scale system

The dimensions and the separation of such meso-scale systems is maintained up to a distance of 100 km or so and later on the wave-length changes indicating variations in the dimensions and in the distance of separation of such systems. At greater distances the resolution between the maxima and minima reduces and the curves flatten. At these distances the wave gets distorted and becomes disorganised under the influence of some other factors of synoptic and regional nature.

4. Theory

It is well known that bulk of tropical precipitation falls in the form of showers caused by convection activity which occur predominantly with random spatial distribution, limited by climatic and regional boundaries (Riehl 1954). There is an interaction between the convective systems and the large scale environment in which they are embedded. Carney and Vincent (1986) have worked out a set of kinetic energy budget equations which explicitly account for meso-synoptic interaction. Charney (1967) suggested that formation of a warm-core tropical depression (in which rain type precipitation predominates) results from a "cooperative, frictionally controlled interaction between an ensemble of cumulus cells and a large scale cyclonic disturbance. In the region of cyclonic vorticity a large scale field of motion, frictionally induced convergence at low levels causes the formation of a deep moist layer which supplies the energy for deep cumulonimbus development". Convergence on synoptic scale in the friction layer increases rainfall through ascending motion. This increases the depth of moist layer in the atmosphere which consequently reduces the lapse-rate which inhibits the formation of thunderstorm clouds. The sinking motion outside the convective clouds reduces the quantity of precipitation but increases the lapse rate. This creates a favourable environment for formation of another convective cloud system. This is shown in Fig. 3. The phenomena thus generates a wave separating zones of convergence and subsidence in the atmosphere. The zones are the areas where cumulus cells develop and form the centres of meso-scale systems and are characterised by heavy rainfall. In the areas of sinking motion, the rainfall amount is reduced. The influence of convection is also borne out by Riehl *et al.* (1973), who in a study of Venezuelan rainfall found out that mean ascent of air occurred during, but not prior to, widespread convective rainfall.

5. Conclusion

The contingency index-distance curves delineate the maximum and minimum values of contingency indices in a wave form having crests and troughs. The maxima and minima demarcate the areas of similar and dis-similar types of rainfall with respect to distance. The maxima are the centres of meso-scale systems and the minima demarcate the boundary of such systems. The distance of the second maximum indicates the separation of such systems.

The present study shows the dimensions of meso-scale systems embedded in a larger rainfall regime in the monsoon months over Madhya Maharashtra and Marathwada as 35-40 km and these systems are scattered at distance of 50-55 km. These values of diameter and separation are maintained up to 100 km beyond which both the values reduce in size and ultimately beyond 120-130 km these systems get disorganised or distorted.

The present study is made for a limited area, *i. e.*, for Madhya Maharashtra and Marathwada subdivisions of Maharashtra for all the synoptic systems causing widespread rainfall during monsoon months in these regions in a composite way. Authors will try to extend this study in other subdivisons of India and for each synoptic system separately in subsequent papers.

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References

Bhaskara Rao, N.S., 1973, "Exercise Storm Exchange", *Vayu Mandal*, **3**, 3, pp. 93-104.

Billa, H.S. and Raj, H., 1967, "Determination of horizontal dimensions of meso-scale precipitating system", *Indian J. Met. Geophys.*, **18**, pp. 383-384.

Brier, G.W. and Allan, R.A., 1951, "Verification of weather forecasts", *Compendium of Meteorology*, Boston, Amer. Meteor. Soc., pp. 841-848.

Carney, T.Q. and Vincent, D.G., 1986, 'Meso-Synoptic Scale Interactions during AVE/SESAME I, 10-11 April 1979, Part 1 : Theorotical Development of Interaction Equations', *Mon. Weath. Rev.*, Feb. 1986, pp. 344-352.

Charney, J.G., 1967, 'Some Remaining Problems in Numerical Weather Prediction', *Advances in Numerical Weather Prediction*, pp. 61-70.

Henry, W.K. and Griffiths, J.F., 1963, '*Meso-scale Features*', *Monsoon Meteorology, International Geophysical Series*, **15**, Academic Press, 1971, pp. 111-112.

Henry, W.K., 1974, 'The Tropical Rainstorm', *Mon. Weath. Rev.*, October 1974, pp. 717-725.

Rainbird, A.F., 1968, '*Meso-scale Features*', *Monsoon Meteorology International Geophysical Series*, **15**, Academic Press, 1971, pp. 111-112.

Riehl, H., 1954, *Tropical Meteorology*, Mc Graw Hill, New York, pp. 93-97.

Riehl, H., Cruz, L., Mata, M. and Muster, C., 1973, 'Precipitation Characteristics during the Venezuela Rainy Season', *Quart. J.R. met. Soc.*, **99**, 422, pp. 746-757.