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Dynamical parameters associated with medium range oscillations of summer monsoon rainfall over India

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सार — इस उपमहाद्वीप के प्रमुख भागों में परिसंचलन प्रतिदर्शों के माध्य के साथ-साथ अधिक एवं कम साप्ताहिक वर्षा के दौरों का अध्ययन किया गया है । क्रियाशील दौरों में देश के अधिकांश भागों में विपरीत प्रकार का याम्योत्तर परिसंचलन होता है । इसमें छुटपुट वर्षा या वर्षा की कमी वाले दौरों में निचले क्षोभमंडल में माध्य परिसंचलन में प्रबल दक्षिणी प्रवाह होता है । ऊपरी क्षोभमंडल (300 मि० बार) में पश्चिमी प्रवाह का क्षेत्र दक्षिण की ओर बढ़ता जाता है और छुटपुट वर्षा के दौरों में 25° उ० के आसपास तक फैल जाता है जबकि अत्याधिक या सामान्य वर्षा के दौरों में देश में 30° उ० तक पूर्वी हवाएं चलती रहती हैं । अपसरण और भ्रमिलता के प्रतिदर्श निचले क्षोभमंडल में कम और छुटपुट वर्षा के दौरान भारत के उत्तरपूर्व और उत्तरपश्चिम के छोरों पर अपसरण के क्षेत्र और ऊपरी क्षोभमंडल में उत्तरपश्चिम भारत में एवं पूर्वी तट में अभिसरण के क्षेत्र को दर्शाते हैं । गति की प्राचलों और ग्रीष्म मानसून के सीजन में सूखे की मध्यम प्रकार के पूर्वानुमान के लिए इनके उपयोग के बारे में चर्चा की गई है ।

ABSTRACT. Mean circulation patterns antecedent and simultaneous with spells of excess and deficient weekly rainfall over the major parts of the sub-continent have been studied. Strong southerly flow in the mean circulation occurs in the lower troposphere during spells of scanty or deficient rainfall, over most parts of the country with opposite type of meridional circulation during active spells. In the upper troposphere (300 mb) westerly flow regime protrudes southwards and extends almost along 25 deg. N during spells of scanty rainfall while during spells of excess or normal rainfall easterly regime prevails upto 30 deg. N over the country. The divergence and vorticity patterns indicate areas of divergence over extreme northeast and northwest India during deficient and scanty rainfall regime in the lower troposphere and areas of convergence over northwest India and east coast in the upper troposphere. The dynamical parameters and their utilisation for medium range forecasting of a drought in the summer monsoon season are discussed.

1. Introduction

The summer monsoon circulation (June to September) over India has been studied by many workers. This season accounts for over 75 per cent of the annual rainfall for most of India. However, there are during these four months considerable variation in amount and spatial distribution of rainfall over the country as a whole. In this study, an attempt has been made to utilise the mean circulation patterns and the associated dynamic parameters for foreshadowing periods of prolonged breaks which may lead to drought conditions in the country. Such a study is believed to be useful for medium and extended range forecasting during southwest monsoon periods.

2. Methodology

Mean circulation patterns associated to spells of active and weak monsoon have been studied by Alexander *et al.* (1978) for developing a synoptic basis for prognosticating weekly rainfall over central India. This study revealed that mean circulation and the weekly circulation anomaly charts are useful tools in identifying prediction for forecasting weekly rainfall distribution over groups of sub-division. Earlier Mooley and Shukla (1972) studied the association of 700 mb topography with the pentad rainfall distribution over the country and its possible use as a prognostic tool. Based on the study carried by Alexander and his collaborators referred to above, De *et al.* (1978) developed a statistical technique for medium range forecasting for rainfall (weekly) for central India using dynamical predictions, like zonal shear anomaly etc. A similar attempt has been made in this study. The following spells were selected :

(*I*) *Active monsoon spells*	*Rainfall distribution*
(*a*) 23-29 July 1980	10 sub-divisions excess, 15 sub-divisions normal, 8 sub-divisions deficient and 1 sub-division scanty.
(*b*) 2-8 July 1980	12 sub-divisions excess, 11 sub-divisions normal, 7 sub-divisions deficient and 5 sub-divisions scanty.
(*c*) 12-18 July 1978	15 sub-divisions excess, 9 sub-divisions normal, 8 sub-divisions deficient and 3 sub-divisions scanty.

Weekly rainfall distribution for week ending on

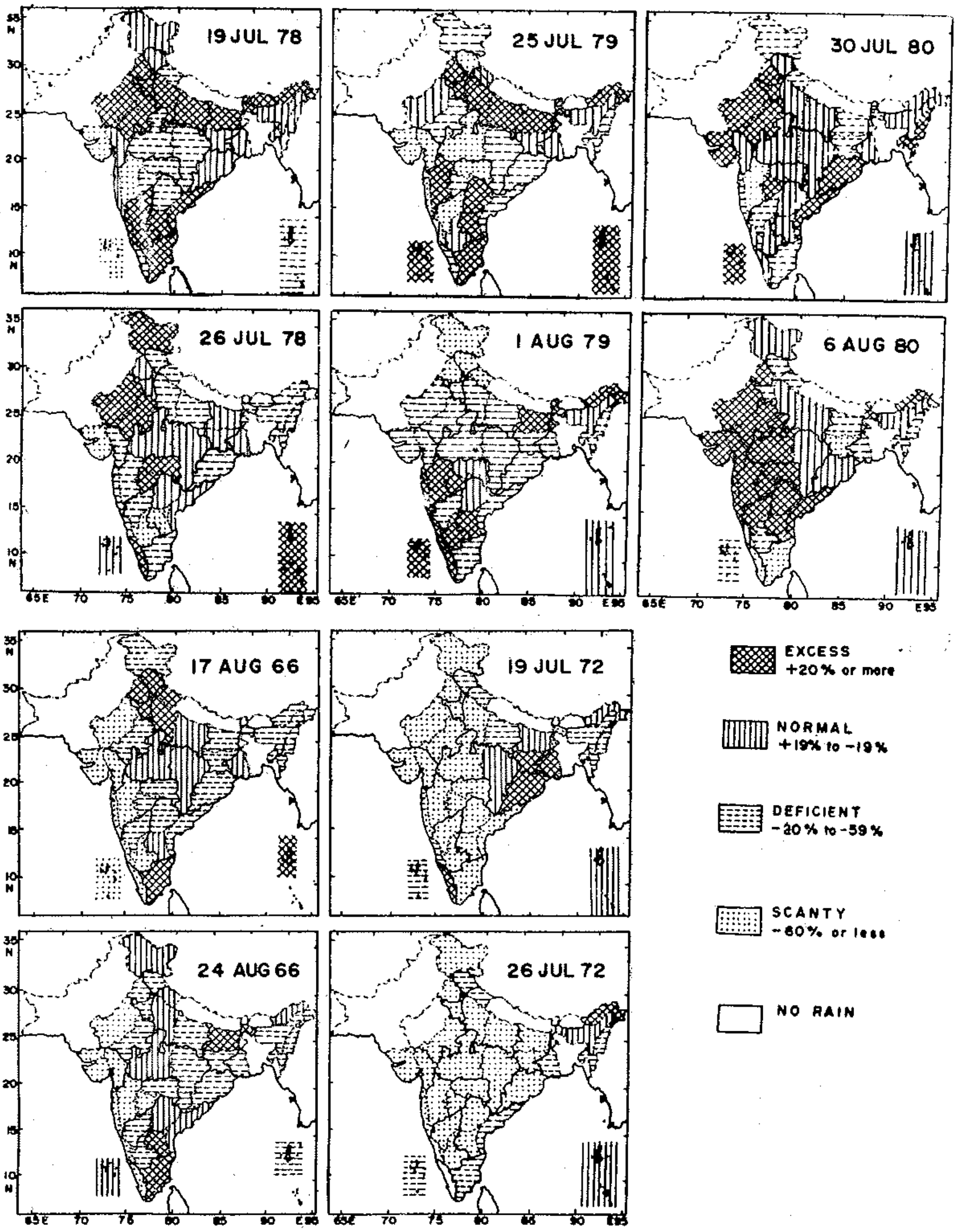

Fig. 1. Weekly rainfall distribution

(*d*) 9-15 August 1978	19 sub-divisions excess rainfall, 8 sub-divisions normal and 8 sub-divisions deficient.
(*II*) *Break or weak monsoon spells*	*Rainfall distribution*
(*a*) 4-10 Jul 1979	2 sub-divisions excess, 4 sub-divisions normal, 13 sub-divisions deficient and 16 sub-divisions scanty.
(*b*) 18-24 Jul 1979	13 sub-divisions excess, mostly along the foot hills and extreme SE Peninsula, 7 sub-divisions normal, 8 sub-divisions deficient and 7 sub-divisions scanty.
(*c*) 25-31 Jul 1979	11 sub-divisions excess, 4 sub-divisions normal, 16 sub-divisions deficient and 4 sub-divisions scanty.
(*d*) 13-19 Jul 1972	4 sub-divisions excess rainfall, 4 sub-divisions normal, 7 sub-divisions deficient and 20 sub-divisions scanty.
(*e*) 11-17 Aug 1966	5 sub-divisions excess, 5 sub-divisions normal, 13 sub-divisions deficient and 7 sub-divisions scanty.

The weekly rainfall distribution for these spells and the following weeks are shown in Figs. 1(a) & 1(b). Mean weekly circulation for these 9 epochs were prepared by using the available upper air data for 850, 700, 500, 300, 200 mb levels. Vorticity and divergence was calculated at different levels at 2½ deg. grid intervals for six of these epochs I (a), (b), (c); II (a), (b) and (c).

3. Discussion

During the southwest monsoon season there are well known fluctuations of the rainfall activity associated with changes in circulation patterns. On a day to day basis these changes have been documented and studied by several workers [Ramamurti *et al.* (1965), Ramaswamy (1965) and Ramamurty (1969)] in the past. Prominent periodicities in the summer monsoon circulations over India have been documented by Ananthakrishnan and Keshavamurty (1970) and Bhalme & Parasnis (1975) and Krishnamurti & Bhalme (1976). Periodicities of four to six days and twelve to fifteen days have been reported and they are closely linked with the medium range (3-7 days) oscillation of rainfall in the country. The problem of prediction of these oscillations in the rainfall is of vital importance for agricultural operations and water resources management.

It is well known that an understanding of the morphology and the dynamics of the large scale flow features are required for medium range forecasting. Namias (1947) made the pioneering work in this field by using the mean circulation charts. In the present study an attempt is made to study the mean weekly circulation pattern associated with these distinct spells of opposite types of rainfall distribution over the country as a whole and determine factors which have a predictive value in deciding the rainfall distribution. A brief description of these features are given below :

(a) *Mean circulation patterns*

One of the important features of the mean circulation patterns is strength and depth of the monsoon westerlies. In the mean circulation corresponding to an active spell zonal components are stronger and extend upto greater depth. The vertical profile of the zonal and meridional components for two typical epochs are shown in Fig. 2. Furthermore, the mean meridional components during the weak monsoon spells are also smaller as compared to an active monsoon spell specially over the area characterised by the monsoon cell. Vertical profile of the meridional components over New Delhi, Port Blair and Nagpur for the two different epochs bring out this point very clearly. In almost all the cases the feature is seen.

(b) *Mean meridional cross section*

Meridional cross section for active and break monsoon spells have been discussed by Ananthakrishnan and Ramakrishnan (1968). Their study indicated meridional flow of southerlies in lower troposphere with northerlies aloft between 18 & 23 deg. N. They called it a "Monsoon Cell". Using the composited data for spells of active and weak monsoon situations, weekly mean meridional flow was computed to obtain a more detailed picture as new upper wind stations have been operating since 1963. The cross sections are shown in the Fig. 3. While there is a broad agreement with the work of Ananthakrishnan and Ramakrishnan (1968), some more details are now available. In the strong monsoon situation, strong monsoon cell extends upto about 300 mb between 18 deg. N and 25 deg. N. Its vertical extent is maximum along 20 deg. N, while north and south of it northerlies appear above 500 mb. South of 10 deg. N in the lower levels, northerlies predominate and above 300 mb southerlies appear. North of 25 deg. N southerlies are confined to 700 mb, and beyond northwards usual Hadley Cell of the northern hemisphere summer appears. While in the weak monsoon the "Monsoon Cell" with southerlies below and northerlies aloft is seen between 18 deg. N and 22 deg. N and is very shallow. At the latitude of its maximum vertical extent, 22 deg. N the cell has a southerly flow upto 500 mb only. The northern hemisphere summer Hadley cell is more prominent and is located north of 24 deg. N and south of 18 deg. N also. This feature of contrasting mean meridional flow pattern can be used as a predicting tool for forecasting persistent periods of excess or scanty rainfall over the country as a whole.

(c) *Mean divergence and vorticity patterns*

Mean divergence pattern shows an extended zone of convergence 3×10^{-5} sec^{-1} from central Bay of Bengal extending northwesterly inland. This slopes in a northwest direction along the axis of the mean monsoon trough at 700 and 500 mb. In the upper troposphere there is an extended area of divergence south of 15 deg. N over the Pensinsula at 200 mb level. Similar patterns of positive and negative relative vorticity are seen on the mean charts.

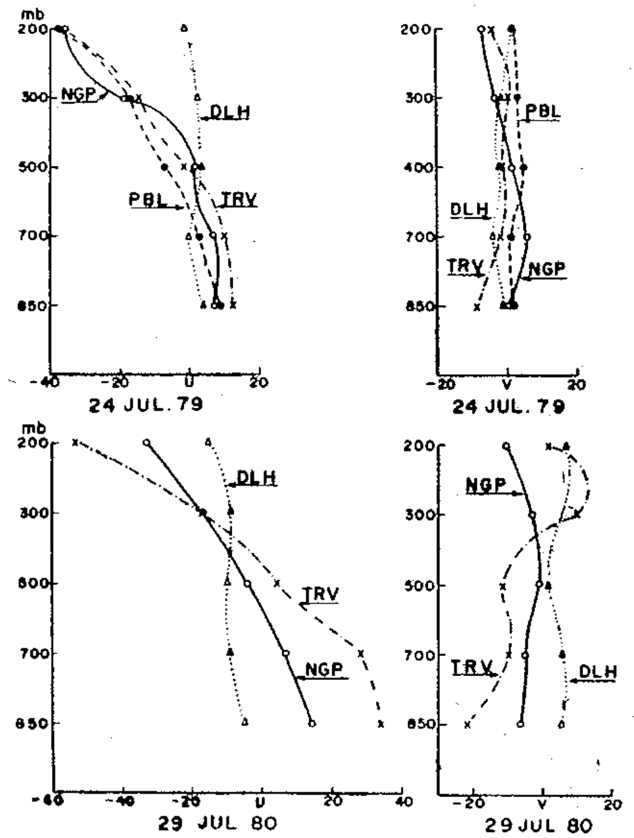

Fig. 2. Vertical profile of mean zonal and meridional wind component for the weeks ending on 24 July 1979 and 29 July 1980

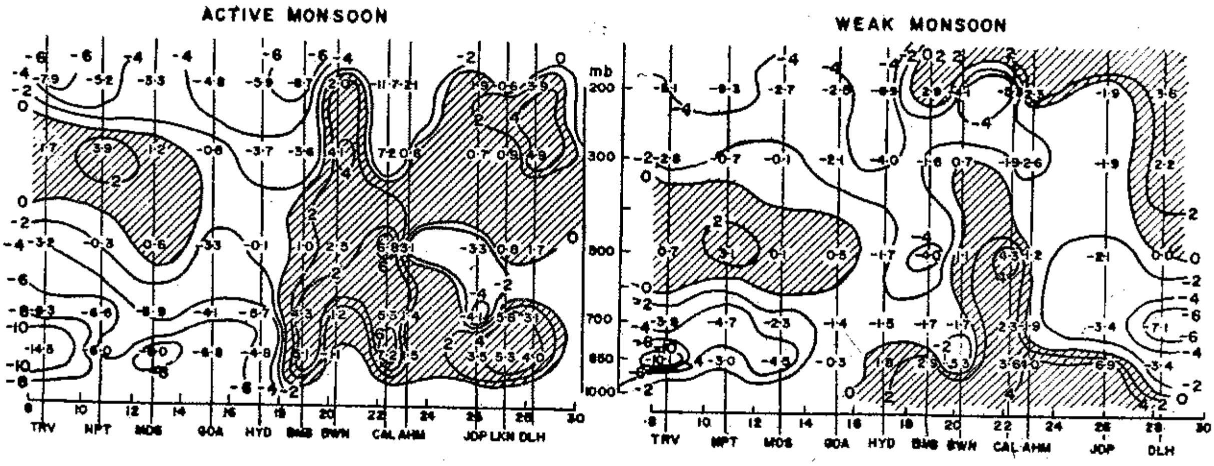

Fig. 3. Mean weekly meridional circulation

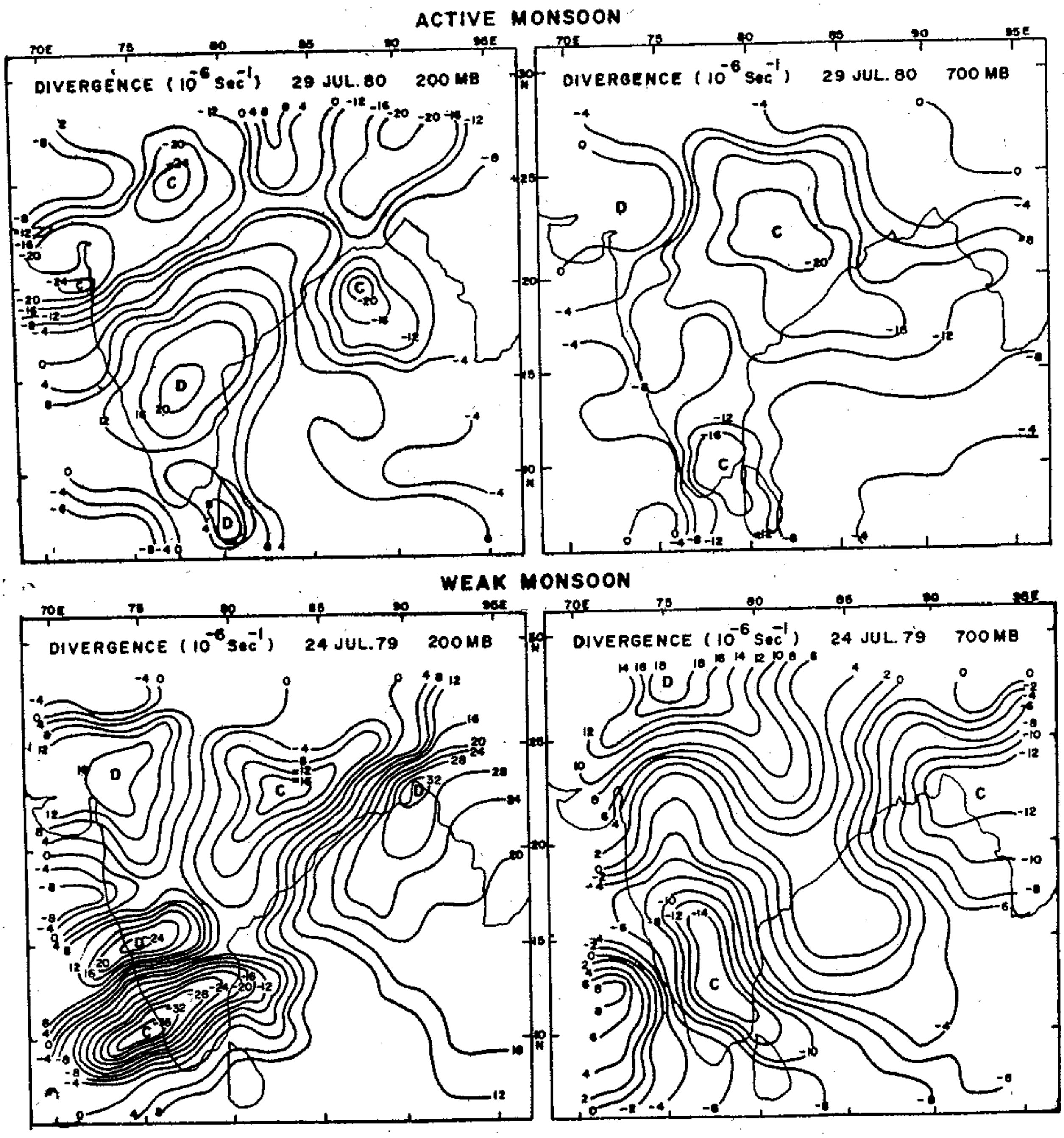

Fig. 4. Divergence patterns

Mean divergence pattern is almost opposite in case of a weak monsoon situation. The zone of low level convergence is now replaced by several cells of diverging air extending upto 500 mb. There may be a zone of convergence confined between 10 & 15 deg. N at 850 and 700 mb levels. The area of upper level divergence is very much reduced and is located over the southern parts of Peninsula. The divergence patterns are shown in Fig. 4.

In the active and weak monsoon spells several important dynamical parameters can be thus obtained from the mean circulation features which may prove useful in predicting the medium range oscillations (3 - 7 days) of rainfall over this country.

4. Conclusions

The following gives a summary of the important conclusions from the study :

(*i*) During spells of active monsoon the zonal monsoon westerlies are stronger and prevail upto greater vertical extent in the mean circulation. While the zonal monsoon westerlies are weaker and are confined to a shallower layer during a weak monsoon spell.

(*ii*) The mean meridional circulation also shows a strong "monsoon cell" with southerlies below and northerlies aloft when the monsoon is strong while the "Hadley cell" predominates when the monsoon is weak and is associated with scanty and deficient rainfall over large parts of the country outside northeast India and southeast Peninsula.

(*iii*) The zone of low level convergence is well marked during active monsoon spell and extends in a northwest-southeasterly direction in the lower troposphere from the central Bay to inland while this is replaced by an area of divergence during the weak monsoon spell. At the upper troposphere the area of divergence in the active monsoon spell is replaced by a zone of convergence or lower divergence during the weak spells.

(*iv*) Some of these relationships are known largely in a qualitative manner and their association with the oscillations of the daily monsoon rainfall distribution are used for short range prediction. Such parameters can be obtained from the mean circulation charts if these are regularly prepared and used as prognostic aids, at the major forecasting centres for foreshadowing the medium range oscillations in the summer monsoon rainfall over India.

(*v*) It is suggested that key dynamical parameters like (a) strength of mean zonal westerlies, (b) strength of the "monsoon cell", (c) areas of mean divergence/convergence in the lower and upper troposphere are monitored from week to week and their fluctuations be used as aids for forecasting weekly rainfall distributions over groups of sub-divisions. A preliminary attempt was made to delineate groups sub-divisions where weekly rainfall occurs in similar spells, like either excess or scanty by Joshi *et al.* (1981). It is hoped that in future study these dynamical parameters will be also correlated to explain with these occurrences.

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