

## Study of synoptic systems associated with intraseasonal variability of summer monsoon — A New Perspective

B.SHYAMALA and G.M. SHINDE

Area Cyclone Warning Centre, Colaba, Mumbai, India

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**सार—** इस शोध पत्र में मानसून '96 के विशेष संदर्भ में महाराष्ट्र और गुजरात क्षेत्रों की दिन प्रतिदिन की अल्पावधि मानसून गतिविधियों के संबंध में पूर्वानुमान जारी करने की अद्यतन प्रेक्षण तकनीकी और विकसित पूर्वानुमान तकनीकी के आधार पर उन महत्वपूर्ण सिनाप्टिक स्थितियों का पता लगाने का प्रयास किया गया है जिनके कारण इन क्षेत्रों में व्यापक वर्षा हुई है।

**ABSTRACT.** An attempt has been made in this paper to identify the important synoptic situations that result in widespread rainfall activity in Maharashtra and Gujarat based on latest observational technology and develop forecasting techniques for day to day short range prediction of monsoon activity in these areas with special reference to Monsoon'96.

**Key words** — Rainfall over Maharashtra, Synoptic situations, Widespread rainfall, Summer monsoon.

### 1. Introduction

Monsoon process plays a vital role in the economy of India where agriculture is mostly rainfed. Temporal distribution of rainfall and intraseasonal variability of monsoon thus are very important forecasting problems not only for the meteorologist but also for the planners. An attempt has been made in this paper to identify the important synoptic situations that result in good monsoon performance in India as a whole as well as Maharashtra and Gujarat based on the all observational data—specially the latest satellite inputs.

### 2. Previous study

Power Spectrum analysis of All India rainfall as well as subdivisional rainfall of Maharashtra reveal two types of periodicities. (Shyamala *et al.* 1993)

- (i) Periodicity of the order of 3-5 days
- (ii) Periodicity of the order of 14-16 days

While the long period oscillation of the seasonal rainfall is generally associated with the activity of the Monsoon trough. Tropical easterly jet and Tibetan High, the short period oscillation is generally attributed to the synoptic scale systems (Krishnamurthy 1976). Thus skill of prediction of short period intraseasonal variability critically depends upon the forecaster's ability to identify these systems and detect their formation.

As per Srinivasan *et al.* (1972) in a detailed-survey of active and weak monsoon situations in Konkan. The im-

portant synoptic situations associated with strengthening of monsoon over Konkan are as follows (based on data upto 1970).

- (i) A trough of low pressure off the west coast on the surface chart.
- (ii) Formation of a monsoon depression over North Bay of Bengal and its movement across the country.
- (iii) Presence of cyclonic circulation off Konkan or over South Gujarat state between 700 and 500 hPa.
- (iv) Strong cyclonic shear in low level westerlies along the west coast.
- (v) Strong pressure gradient along the west coast.

It was also observed by them that it is difficult to clearly isolate the individual contribution of the systems so that it was not possible to prepare any table giving percentage number of occasions of active or vigorous monsoon with each of the above situations Rao (1976). The role of Monsoon depression as efficient rain producing systems have been intensely studied by various Meteorologists. Rao (1976) also prepared a statistics of depressions and cyclonic storms in the monsoon season (Table 1) based on 1890-1970 data and identified the role of depression and cyclonic storms in the monsoon process. It is seen from the table that the average seasonal frequency of depression and storms in the monsoon season is 7.5 and 2.0 respectively.

TABLE 1  
Number of cyclonic disturbances (1891 - 1970) (Y.P. Rao 1976)

	June		July		August		September	
	D	S	D	S	D	S	D	S
Bay of Bengal	71	35	107	38	132	26	141	32
Arabian Sea	18	15	9	3	2	2	9	5
Land area	12	1	39	1	42	0	21	1
Total system	101	51	155	42	176	28	171	38
Total from Jun to Sep.	Dep. 603				Storm 159			
Annual average	Dep. 7.5				Storm 2			

TABLE 2  
Synoptic systems affecting Indian monsoon region during June to September (1991-1996)

Year	CS	D	Lopar/WML	Cycl. cir in lower & middle troposphere	All India monsoon performance (%)
1991	0	4	10	17	92
1992	1	2	11	39	93
1993	0	1	14	33	101
1994	1	1	14	20	110
1995	0	2	11	40	100
1996	2	1*	16	39	103
Total	4	11	76	188	
Average	0.7	1.8	12.7	31.7	

\* Land depression formed over Bihar Plains

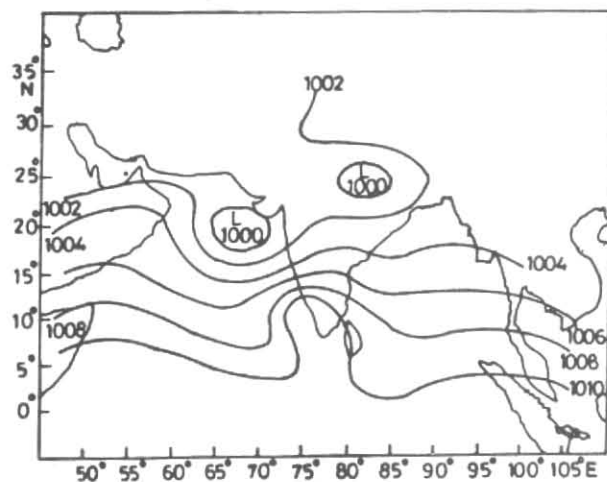


Fig.1. Low over Saurashtra & Kutch adjacent NE Arabian Sea WDRR in Konkan, South Gujarat region and Saurashtra on 17 July 1996, 0300 UTC at surface chart

The rainfall potential of the Monsoon depression has been analysed both in the direct zone of the convergence as well as in distant rainfall belts Mooley (1973) and Shyamala (1982). The active/vigorous situations in Konkan when monsoon depressions form over Bay are associated with formation of low level circulation over North Maharashtra coast-South Gujarat coast (Shyamala 1982). Many Meteorologists have attempted to correlate the rainfall performance in India to the number of monsoon depressions hence causing apprehension in the minds of the planners that a year of low frequency of monsoon depres-

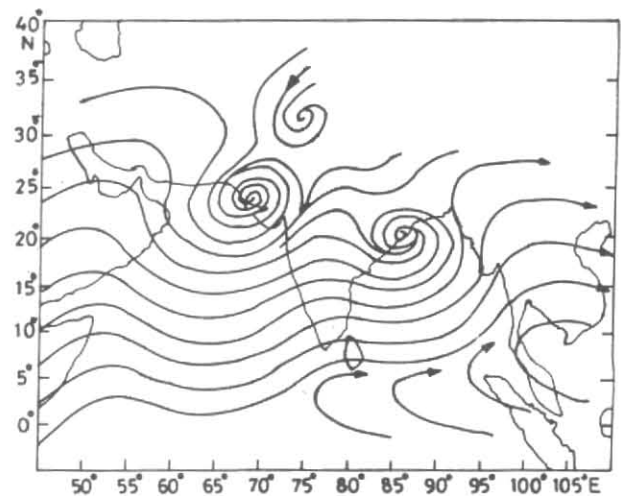


Fig.2. Circulation over Saurashtra & Kutch and adjacent NE Arabian Sea WDRR in Saurashtra, Kutch, South Gujarat region and Konkan on 19 July 1996, 0000UTC at 850 hPa

sion may lead to deficiency in the rainfall performance of the country.

### 3. Present study-data and methodology

The main interest in this study was due to the significant observation that in this decade from 1990, the number of monsoon depressions have been very few but still the monsoon performance in India, as a whole as well in most sub-division of India has been very good. All available data including the satellite data were critically analysed to iden-

TABLE 3  
Synoptic systems affecting Maharashtra-Gujarat coast during June to September

Year	CS	D	Lopar	Cycir	Offshore trough
1991	-	1	4	12	Present on most days of the season
1992	-	2	6	11	-do-
1993	-	-	3	11	-do-
1994	1	1	12	3	-do-
1995	-	-	4	13	-do-
1996	1	1*	6	12	-do-
Total	2	5	35	62	
Average	0.33	0.8	5.8	10.3	

\* Land depression formed over Bihar Plains.

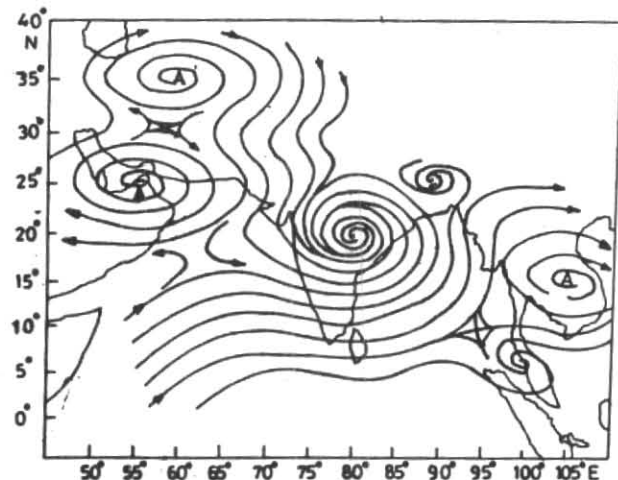


Fig.3. Circulation over Vidarbha and neighbourhood WD rainfall in Vidarbha - Marathwada on 7 July 1996, 1200 UTC at 700 hPa

tify what caused active, widespread monsoon conditions in the absence of monsoon depressions or when their frequency is very low.

Daily working charts of ACWC Mumbai and the satellite imageries from INSAT and NOAA were analysed for this purpose.

#### 4. Analysis

##### 4.1. All India rainfall

Table 2 shows the synoptic systems that affected the Indian Monsoon region during 1991-1996. A number of interesting features are observed.

- (i) Total number of cyclonic storms and depressions was 4 & 11 respectively. In 6 year period giving annual average of 0.7 and 1.8 as against the average of 2 and 7.5 as given by Rao (1976).
- (ii) In spite of low frequency of monsoon depressions, it is seen that the all India monsoon performance during these years was very good within 10% of the normal, 4 years showing even positive departures. It therefore became necessary to examine the data with a view to find out whether any significant feature is noticed in these

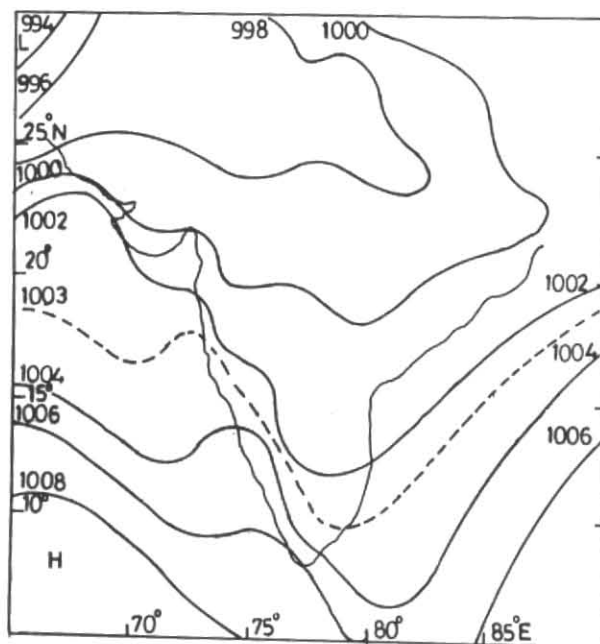


Fig.4. No system present on the surface on 7 July 1996, 1200 UTC at surface chart

years, that contributed to the observed rainfall activity.

- (iii) On further examination of the table it is seen that 76 low pressure areas formed and moved during these years with average of 12.7 per year.
- (iv) In addition, more significantly 188 cyclonic circulations in lower and middle troposphere were observed during these 6 years with average of 31.7 circulations per season and these were invariably associated with widespread rainfall.

Thus, it became evident that there is need to recognise the cyclonic circulations and low pressure areas as important rain producing systems in addition to monsoon depressions.

##### 4.2. Rainfall in Maharashtra and Gujarat

Maharashtra and Gujarat which are regions of operational responsibility of ACWC Mumbai were selected for detailed analysis of the synoptic systems. The working charts and the satellite pictures were analysed critically for

**TABLE 4**  
**Week- by- week analysis of 1996 monsoon for Maharashtra-Gujarat whenever fairly widespread/widespread rainfall was experienced in the region**

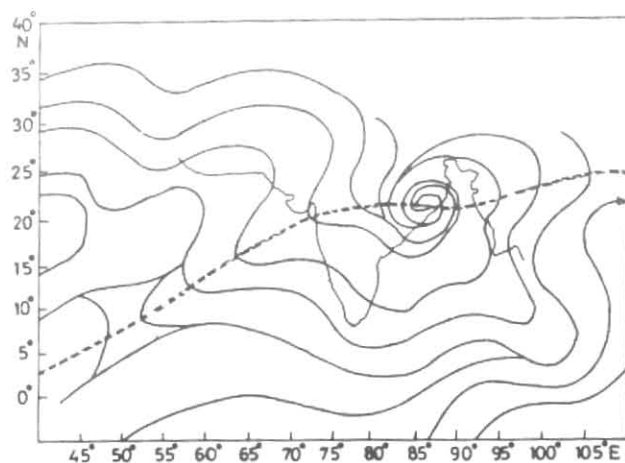
Week	CS	D	WML	Cycir	Remarks
June 13-19	1	-	-	-	Cyclonic storm in East Central Arabian Sea during 17-18 June & active/vigorous conditions in Konkan on 17th & 18th June
July 4-10	-	-	-	3	(i) Cyclonic circulation over Vidarbha upto mid-tropospheric level. (7th & 8th July) (ii) Cyclonic circulation over North Telengana and adjoining Marathwada between 1.5 and 5.8km (8 & 9 July) (iii) Cyclonic circulation over North-west Madhya Pradesh and adjoining North Gujarat region. (8 & 9 July) All these 3 circulations resulted in wide-spread rainfall in the region (7th to 10th July)
11-17	-	-	1	1	(i) Low pressure area over Bay (14th) (ii) Cyclonic circulation over Vidarbha, Maharashtra, Madhya Maharashtra, North Konkan during 15th to 17th. Widespread rain in Marathwada, Vidarbha and Gujarat region during 15th to 17th
18-24	-	-	2	1	(i) Well Marked Low over Northeast Arabian sea (18th & 19th) (ii) Low over Bay on 19th (iii) Circulation over Saurashtra and Kutch and Northeast Arabian Sea on 21st, 22nd and 23rd giving widespread rain
25-31 July	-	1	-	-	(i) A well marked lopar over Bay of Bengal on 25th which concentrated into a depression over Bihar Plains. It moved further westwards and weakened into a lopar over west Madhya-Pradesh adjoining North Gujarat region. Widespread rain occurred in Maharashtra-Gujarat area during 27th to 31st
August 1-7	-	-	1	-	(i) Lopar over Bay on 1st and 2nd Aug. became less marked on 3rd however associated cycir over Northwest MP and adjoining Gujarat region 4th to 6th
8-14	-	-	-	1	(i) Cycir over Vidarbha with East-West trough over Maharashtra at 500 hPa on 8th & 9th. This is seen as a very good cloud signature. (Fig. 5)
15-21	-	-	1	1	(i) Lopar over the Bay on 15th (ii) Cyclonic circulation over NE Madhya Pradesh and neighbourhood on 20th & 21st. Rain in Vidarbha and Marathwada on 20th & 21st
22-28	-	-	1	1	(i) Cyclonic circulation over North Maharashtra coast and adjoining South Gujarat on 25th (ii) Lopar over Bay on 26th with well defined Monsoon trough from the system to Marathwada in the lower level giving widespread rainfall from 25th to 28th
29 Aug - 4 Sept	-	-	-	2	(i) Cyclonic circulation over Vidarbha 29th to 30th (ii) Cyclonic circulation over Gujarat region from 30th to 1st Sept. (iii) Widespread rain in the region from 29th to 31st
5-11	-	-	-	1	(i) Cyclonic circulation over Marathwada which moved over North Gujarat region during 6-11 and give widespread rain during the week
12-18	-	-	-	1	(i) Cyclonic circulation over Vidarbha Marathwada, North Madhya Maharashtra, North Gujarat region during 12th to 18th giving widespread rain

identification of synoptic situations which resulted in fairly widespread/widespread rainfall distribution in Maharashtra and Gujarat generally accompanied by active monsoon condition.

Table 3 gives the list of this analysis.

- (i) There were 2 cyclonic storms and 5 depressions only during this period (average freq. 0.3 and 0.8 resp.).
- (ii) There were 35 low pressure areas either in Bay, in Arabian Sea or over land (average freq. 5.8).
- (iii) There were 62 cyclonic circulations which gave active monsoon conditions and widespread rainfall in various sub-divisions of Maharashtra and Gujarat (average freq. of 10.3).

This analysis also revealed that cyclonic circulations and low pressure areas play a significant role in the rainfall



**Fig.5.** East-West trough across Maharashtra-South Gujarat widespread rainfall in the region on 8 August 1996, 1200 UTC at 500 hPa

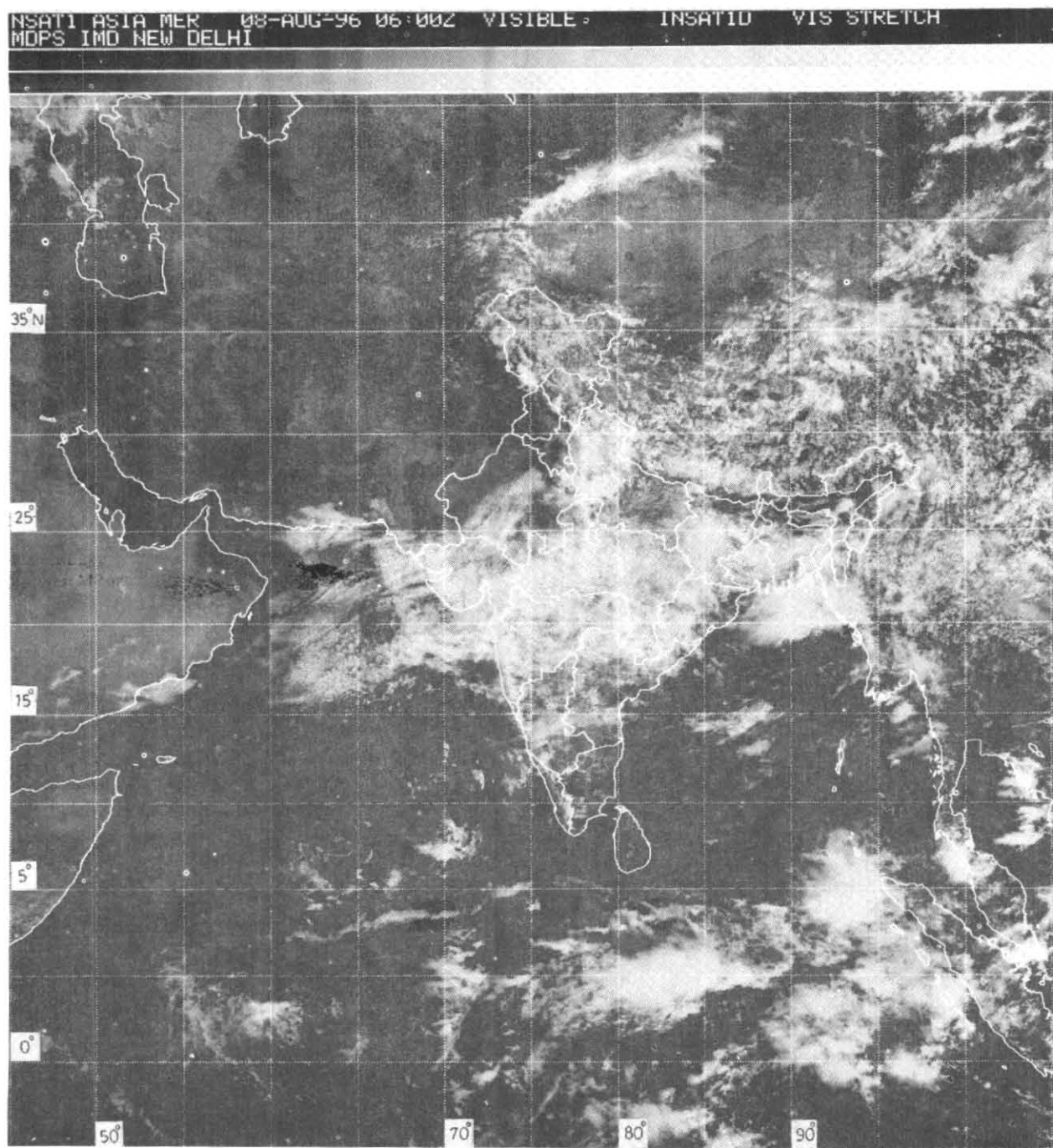


Fig.6. Insat-1D cloud picture (visible) of 8 August 1996, 0600 UTC

distribution in Maharashtra and Gujarat and are crucial in deciding the performance of the monsoon in these areas.

##### 5. Analysis of monsoon 1996

Monsoon season 1996 was analysed week by week for fairly widespread/widespread rainfall in Maharashtra and Gujarat and results are given by Table 4.

It is seen from this table.

(A) There are 5 important synoptic systems that caused widespread active monsoon in Maharashtra and Gujarat during 1996.

They are:

(i) Cyclonic storms

(ii) Depressions

(iii) Lopar/Well marked low pressure areas

(iv) Cyclonic circulations

and (v) Trough off west coast with offshore vortices.

(B) The trough off west coast was present on most days of the season: this trough alone does not produce widespread rainfall or active monsoon conditions unless accompanied simultaneously by any of the other four conditions under (i) and (iv).

(C) Formation of monsoon depression over Bay was totally absent in 1996 but rainfall in Maharashtra has been normal or excess in 21 out of 30 districts of Maharashtra.

(D) 6 low pressure areas contributed to active monsoon in Maharashtra. South Gujarat, Saurashtra and North Konkan (Fig. 1).

(E) 12 cyclonic circulations in lower and middle troposphere over various areas gave wide spread rainfall in the region.

These cyclonic circulations were of 2 types.

(i) Circulations over Saurashtra, South Gujarat region and adjoining Northeast Arabian Sea at 0.9km above sea level and 850 hPa which give rise to widespread rainfall activity in North Konkan. South Gujarat region and Saurashtra. (Fig. 2)

(ii) Circulations over Vidarbha and adjoining Marathwada generally extending upto 700 hPa which give rise to widespread rainfall activity in Vidarbha & Marathwada only (Figs. 3, & 4). No surface system is present.

(F) The rainfall activity on 8th August was due to the east-west trough across the region at 500 hPa (Fig.5). It is also interesting to see the east-west band of associated cloudiness (Fig. 6).

(G) Rainfall in South Konkan & South Madhya Maharashtra is generally associated with trough off coast with embedded vortices so that widespread rain is realised in these sub-divisions on more than 80% days of the season due to presence of the trough.

## 6. Conclusions

(i) There has been definite decrease in the number of monsoon depression during the period 1991-96 with an average frequency of 1.8 as compared to long period average of 7.5 depression. In spite

of this, the monsoon performance has been very good on all India basis mostly with positive departures. This has been mainly due to the occurrence of 188 cyclonic circulations (average 31.7 per year). Thus, the occurrence or non occurrence of the cyclonic circulation appears to be one of the major deciding factors in the ultimate monsoon performance.

(ii) For Maharashtra and Gujarat also, occurrence of 10.3 circulations per year during 1991-96 has resulted in Excess/Normal rainfall in the area. These circulations are of 2 types :

(a) Low level circulations between 850-700 hPa over Saurashtra and adjoining Northeast Arabian Sea resulting in heavy widespread rain in North Konkan, South Gujarat region and Saurashtra.

(b) Cyclonic circulation over Vidarbha between 0.9 and 3.1km which result in widespread rain in Vidarbha and Marathwada.

(iii) These circulations have been found to give widespread rainfall during next 24 hours and therefore are very useful as short range predictors of intra-seasonal variability of rainfall.

The above study clearly illustrates that cyclonic circulations are very important synoptic situations for widespread rain in an area. Role of cyclonic circulations as potential rain producing mechanism has to be recognised along with other already identified systems like depressions and storms. While the depressions produce concentrated localised heavy rain, these circulations produce benevolent rainfall over a large area and thus contribute significantly to the Indian Summer Monsoon rainfall.

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