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## A COMPARATIVE STUDY OF SUMMER MONSOON FEATURES OVER INDIA DURING 1987 TO 1997

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*Abstract:* In this paper comparative study of characteristic features of summer monsoon, viz. onset and withdrawal, synoptic situations causing heavy rainfall, average seasonal monsoon rainfall over the country and floods generated in Indian rivers in each monsoon season has been made on the basis of 11-years' data (1987 to 1997). It is shown that each monsoon season is quite unique in its behaviour and no two monsoons are alike.

### INTRODUCTION

India being an agricultural country, vagaries in summer monsoon rainfall distribution is of great interest and importance to agriculturists, administrators and a host of others who are directly or indirectly involved with water, its management and distribution in the country. Dhar and Nandargi (1992) on the basis of 5 years' (1987-1991) data of summer monsoons, have studied the broad meteorological situations which occurred over the country and produced different magnitudes of average seasonal rainfall. Frequency of these situations as well as floods generated by these rains in the major river systems of India were also studied. In the present case, this study has been extended by another six years with a view to know whether the conclusions arrived at in the earlier study have in any way been modified by using the data of eleven monsoon seasons in a row from 1987 to 1997.

### DATA USED

In the present study 1-year data of summer monsoons (1987-1997) have been examined based upon the information contained in the India Meteorological Department (IMD) publications like Daily and Weekly Weather Reports, Monthly and Annual Summaries, etc.

Before the actual study is taken up a brief summary of normal summer monsoon features is given by way of information.

### NORMAL SUMMER MONSOON FEATURES

The IMD fixed long ago 1st June to 30 September as the summer monsoon season (hereafter referred to as monsoon season) for the Indian sub-continent although



invariably monsoon extends even beyond the month of September. During this season, humid monsoon weather prevails over the entire country. Irrespective of onset and withdrawal dates, rainfall occurring during June-September period, is considered by the IMD as the monsoon seasonal rainfall of the country. It has been estimated to be about 890 mm which is about 76% of mean annual rainfall.

Over a long period of years, it has been observed that the activity of monsoon has three broad phases which are a) onset phase, b) active monsoon phase, and c) withdrawal phase. These three phases are briefly described below:

**a) Onset phase:** Normally, monsoon sets in over south Kerala by about 1st June by the advancing monsoon currents which have their origin south of the equator (Rao, 1976; Das, 1988). As per the IMD records of the past 100 years, the onset of monsoon over Kerala was as early as 11 May in the year 1918 and as late as 22 June in the year 1972 (Shukla, 1987). Although there have been variations in the monsoon onset dates by a few days to a week in different years (standard deviation being about 7 to 8 days (Das, 1987)) by and large, the monsoon arrives in India quite regularly every year by first of June or near about that date.

Before its arrival at Kerala, the main monsoon current divides itself into two main branches, viz. the Arabian Sea branch and the Bay of Bengal branch. The Arabian Sea branch advances northwards and eastwards along the Indian Peninsula, while the Bay of Bengal branch advances along the Burma-Bangladesh coast, into extreme northeastern states of India and is then deflected by the mountain ranges of the eastern Himalayas towards the plains of northern and central India. It is generally seen that by about 15 July, the entire country is covered by both branches of the monsoon. In other words, normally the monsoon takes about 45 days to establish itself over the entire country (see Fig 1).

**b) Active phase:** Having established itself, the monsoon remains by and large active over the country for about another 47 days (i.e. from about mid-July to 1st September) which is the most crucial period for the country for obtaining well distributed rainfall for sowing and other agricultural operations. In this period the entire country receives moderate to heavy rainfall in association with synoptic situations which interact with prevailing humid monsoon air and cause rainfall over different parts of the country.

In this period cyclonic disturbances like low pressure areas, depressions, deep depressions, and cyclonic storms move through the country from the neighbouring seas and play an important role in maintaining and strengthening the monsoon activity over the country. Besides these factors, seasonal monsoon trough and its north-south movement, the westerly troughs, variation in the upper air Tibetan anticyclone, El-Nino and La-Nina etc. play an important role in maintaining the activity of monsoon over the country between the epochs of onset and withdrawal.

Often in this period, there are occasions when monsoon activity becomes weak or sluggish and consequently rainfall activity over different parts of the country becomes weak. Another setback to monsoon activity over the country occurs during the monsoon period when the axis of the seasonal monsoon trough over north Indian

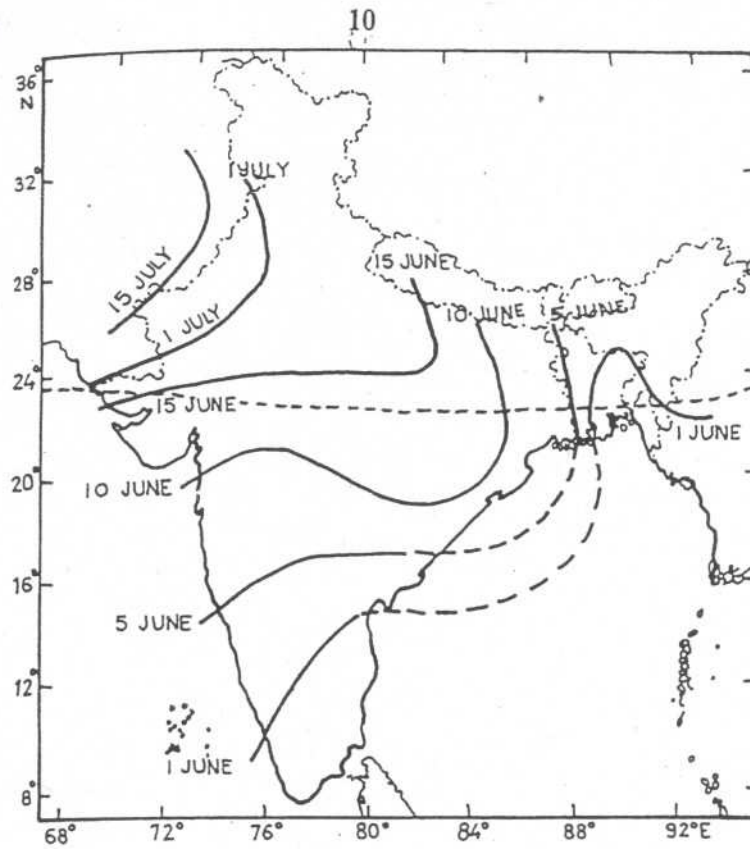


Fig 1 Normal dates of Onset of Summer Monsoon over Indian region (Courtesy: IMD, India)

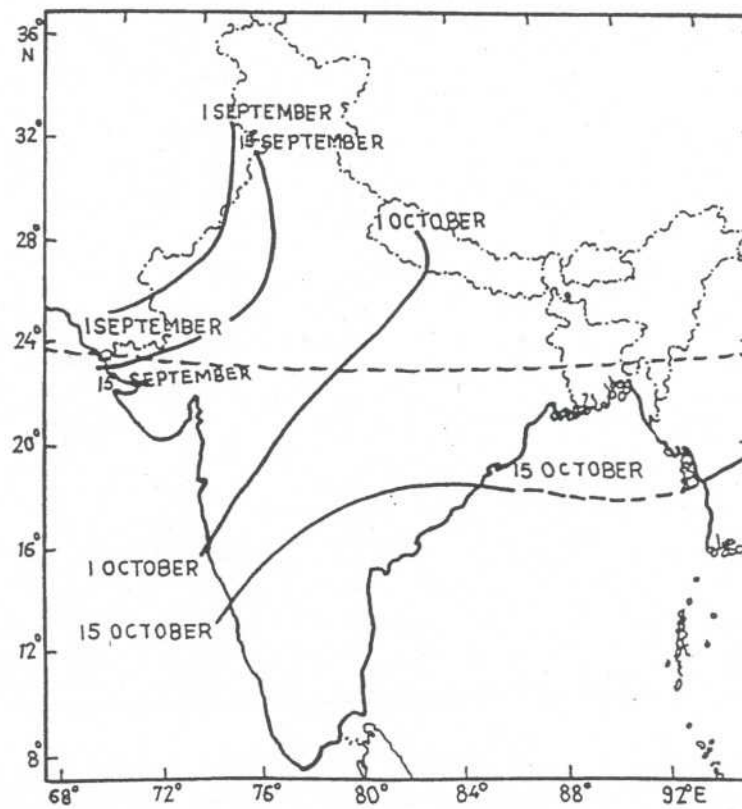


Fig 2 Normal dates of Withdrawal of Summer Monsoon over Indian region ( Courtesy: IMD, India)



Table 1 : Onset and withdrawal dates and duration of monsoon over the contiguous Indian region

Details about monsoon	Years										
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Onset date of monsoon over Kerala	2 June	26 May	3 June	19 May	2 June	5 June	27 May	28 May	8 June	3 June	9 June
Date by which entire country was covered by monsoon	27 July	1 July	2 July	1 July	19 July	14 July	5 July	30 June	13 July	30 June	19 July
Time taken to cover the entire country	56 days	37 days	30 days	44 days	48 days	40 days	40 days	34 days	36 days	28 days	41 days
Date of withdrawal of monsoon from northwest	12 Sept.	12 Sept.	14 Sept.	27 Sept.	18 Sept.	17 Sept.	21 Sept.	16 Sept.	13 Sept.	15 Sept.	6 Sept.
Date of final withdrawal from the peninsula	24 Oct.	12 Oct.	13 Oct.	17 Oct.	18 Oct.	19 Oct.	20 Oct.	17 Oct.	23 Oct.	11 Oct.	8 Oct.
Time taken to withdraw from the country	43 days	31 days	30 days	21 days	31 days	33 days	30 days	32 days	41 days	27 days	33 days
Actual period of monsoon (days)	145	140	133	152	139	137	147	143	138	131	122
Normal duration of monsoon (days) (As per IMD's convention)	122 days (1 June to 30 September)										
Deviations from normal (days)	+23	+18	+11	+30	+17	+15	+25	+21	+16	+9	0
Monsoon rainfall over contiguous Indian region as % of normal (Jun. to Sept.)	-18%	+18%	-1%	+7%	-7%	-8%	+1%	+11%	0	+2%	+2%

Note : The dates of onset, withdrawal, etc. have been taken from IMD's publications like Weekly and Monthly Weather Reports, Annual Weather Summary, Mausam Journal of each of the above years

plains shifts to the foot of the Himalayas and a complete "break" in monsoon activity over the country sets in (Ramamurthy, 1969; Dhar et al., 1984). This results in vigorous rainfall activity over the eastern and central Himalayas from Assam to Garhwal. During the "break" situations, the Himalayan rivers (especially the major eastern rivers like the Brahmaputra, the Teesta, the Kosi, the Gandak and the Karnali)

rise in high floods due to excess rainfall in their Himalayan catchments, while northern Indian plains are reeling under semidrought conditions. Such type of break situations have occurred in many years in this country especially during the drought years of 1877, 1905, 1911, 1918, 1951, 1965, 1972, 1979, 1982 and 1987.

c) **Withdrawal phase:** The last stage of the monsoon is the withdrawal phase which, more or less, starts from 1st September. In this phase, monsoon first withdraws from north and northwest India and then from central parts of India and northern half of the peninsula. Thus the region of the country (i.e. northwest India) where monsoon reaches the last, is the first region from which it withdraws first (see Fig.2). As a result, northwest India hardly experiences monsoon for a duration of about 45 days.

#### DISCUSSION ON THE BEHAVIOUR OF MONSOON DURING 1987-1997

In India, as mentioned earlier, according to IMD's convention, the summer monsoon season is confined to the 4 month period from 1st June to 30th September, a duration of 122 days, although it persists invariably beyond September and up to about 15th October over southern half of the Indian Peninsula (see Fig.2). Table 1 gives the actual yearly dates of monsoon onset over the Kerala coast, the dates by which the entire country was covered by monsoon and the dates of withdrawal of monsoon from the country during the 11-year period (1987-1997) as mentioned in IMD's Monsoon Bulletins of this period.

Although the normal duration of the monsoon over the country as per IMD's convention is 122 days, but if we consider the actual duration of monsoon from onset to withdrawal during the 11-year period, it appears that monsoon duration varied from 122 days in 1997 to 152 days in 1990 (see Table 1). Normally the monsoon takes about 45 days to cover the entire country, but during the 11-year period, it took the maximum of 56 days in 1987 while in 1996, only 28 days were taken to cover the country (see Table 1). Such variation in duration of monsoon is one of the causes of seasonal variability of rainfall.

As stated earlier, according to IMD's convention, monsoon period is considered from 1st June to the end of September, but it is seen from 11-year's data that actual withdrawal of monsoon took place beyond 30th September. It took place as early as 8 October in 1997 and as late as 24 October in 1987 (see Table 1). So far as the actual time taken by the monsoon to withdraw from the country is considered, it took only 21 days in 1990 and 43 days in 1987 (see Table 1).

It is also seen from Table 1 that the actual monsoon season over the country in most of the years (i.e. 10 out of 11 years) was more than the normal period of 122 days. In fact, the deviation from the normal duration showed that it varied, during the 11 year period, from 0 (1997) (nil duration) to 30 days (1990). Rainfall that occurred during these so called "extra monsoon days" (i.e. monsoon days beyond September 30) is normally not considered as "monsoon rainfall" by IMD in their publications. This does not appear to be correct, as this rainfall is also received from the same monsoon system. To overcome this lacuna, it is suggested that monsoon rainfall may be considered from onset date to withdrawal date.



The area averaged seasonal monsoon rainfall of the country from 1st June to 30th September (as per IMD's convention) has been worked out for each monsoon season from 1987 to 1997 and these average values are also given in Table 1 by way of information. It is seen that the monsoon rainfall varied from - 18% (in 1987) to + 18% (in 1988).

### CYCLONIC DISTURBANCES AND MONSOON SEASONS

As stated earlier, various meteorological situations which move through the country during the monsoon period are responsible for causing moderate to heavy rainfall over the country. However, it is shown by Kripalani and Kulkarni (1997) on the basis of seasonal and annual rainfall data of about 135 stations for 25 to 125 years over south-east Asian region that although there are year to year random fluctuations in rainfall distribution, there are certain epochs of above and below normal rainfall over some regions. According to them, within season, these epochs are not forced by the El Nino/La Nina episodes. They have also shown that extreme drought and flood situations tend to occur when the internal epochal behaviour and the external forcing of El Nino/La Nina events are phase-locked.

In view of the above, the major role in the spatial distribution of rainfall during the monsoon period is played by cyclonic disturbances like low pressure areas, depressions, deep depressions and even cyclonic storms. Table 2 gives the list of these disturbances during the 11-year period (1987 to 1997).

In the years 1988 and 1994 maximum number of 17 and 18 such cyclonic disturbances occurred while in the year 1987 only 10 such disturbances occurred over the country (see Table 2). The monsoon seasons of the years 1988, 1990 and 1994 were comparatively good rainfall years for the country when +18%, +7% and +11% above normal rainfall respectively was experienced (see Table 1). During the monsoon season of 1987 only 10 disturbances were experienced and as rainfall over the country was of the order - 18% below normal, it was considered as a drought year.

Table 2 : Frequency of cyclonic disturbances and number of major rivers affected by floods during monsoon seasons of 1987 to 1997

Years	Frequency of cyclonic disturbances			No. of major river affected by floods
	Cyclonic Storms	Deep Depressions/ Depressions	Low Pressure Areas	
1987	-	3	7	30
1988	-	3	14	32
1989	1	4	11	28
1990	-	4	10	37
1991	1	4	8	34
1992	1	2	10	25
1993	-	1	15	34
1994	1	1	16	33
1995	1	2	11	33
1996	2	2	8	40
1997	1	5	2	38

It is seen from Table 2 that when a large number of these cyclonic disturbances traverse the country during the monsoon season, the country invariably receives fairly well distributed rainfall as is evident from the years 1988, 1990 and 1994 (see Table 1). It may, however, be mentioned that a high frequency alone of these disturbances does not cause well distributed rainfall, but the rainfall distribution depends to a large extent upon their life-span, rate of movement and the tracks followed by them.

Heavy rainfall caused by these tropical disturbances in the catchment areas of rivers is responsible for causing serious floods in the river systems of the country. There are about 52 major river basins and it is seen that in each monsoon season of the period from 1987 to 1997, 25 to 40 rivers (see Table 2) got flooded due to heavy rains in their respective catchment areas. Floods have also occurred even in drought years due to heavy rainfall caused in one or other part of the country by these disturbances. In the drought year of 1987, floods did occur in 30 rivers (see Table 2), mostly in the rivers of northeast India, while in the best monsoon year of 1988, floods occurred in only 32 rivers, thereby indicating that rainfall magnitudes received do not give any clue to the number of rivers that will get flooded.

#### CONCLUDING REMARKS

In this brief survey we have seen that during the 11-year period (1987-1997) no two monsoon years are similar or alike. Every monsoon season is unique so far as its onset, advance or withdrawal is concerned. This is perhaps due to the fact that too many meteorological factors come into play with the monsoon air mass or interact with one another during their passage through the sub-continent. In some years some factors are more active than others, while in other seasons new factors come into play. In short there is enormous variety in each monsoon season. Hence the Indian summer monsoon may be described in the same manner as Shakespeare described Cleopatra in his famous drama "Anthony and Cleopatra" like:

*"Age cannot wither her, nor custom stale her infinite variety",*

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## PROLONGED COLD-AIR CUSHION IN THE CARPATHIAN BASIN IN NOVEMBER 1978 AND OBSERVATIONS OF A GLORY

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*Abstract.* The case of a prolonged spell of cold anticyclonic conditions with persistent fog is described for the Carpathian Basin in November 1978. Observations of glory-type phenomena in fog formed by street lamps are also related.

### INTRODUCTION

In late autumn under conditions of long-term anticyclonic weather situations, it often happens that in the lower 1 to 1.5 kilometres above the Carpathian Basin cold masses of air are to be found. Under concurrent effects of wet oceanic air-streaming together with strong air pollution, this phenomenon can be observed for several days on end. Above this cushion of cold air and static airstreams it sometimes happens that the temperature inversion leads to a deep layer of fog which lasts for weeks. The persistence, intensity and stability of fogs of this type can be understood from the macroscopic situation.

### DESCRIPTION AND INTERPRETATION

In November 1978 fog or stratus clouds resulting from it were observed for 25 days in the area of the three Koros rivers (the Fast-, the Black-, and the White-Koros) in the neighbourhood of Salonta (population 20 000). The most remarkable late-autumn anticyclone for several decades that was responsible for this fog had