

## Relationship between monsoon onset over Thiruvananthapuram and Mumbai and rainfall over Kerala and Konkan

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**सार** – इस शोध-पत्र में दो स्थानों नामतः थिरुवनन्तपुरम और मुम्बई का चयन करके यह पता लगाने का प्रयास किया गया है कि क्या मानसून के आगमन की तारीख का क्रमशः केरल और कोंकण में होने वाली वर्षा के साथ कोई संबंध है। समूचे देश के लिए भारतीय ग्रीष्मकालीन मानसून वर्षा (आई. एस. एम. आर.) के साथ मानसून के आगमन की तारीख के संबंध की भी जाँच की गई है। इस अध्ययन के लिए 100 वर्षों (1901–2000) के आँकड़ों का उपयोग किया गया है।

$\chi^2$  विश्लेषण की सहायता से आँकड़ों की एकरूपता और वर्षा के अन्य लक्षणों की जाँच की गई है। केरल और कोंकण में अकाल और मौसम संबंधी बाढ़ की समकालिक घटनाओं की आवृत्ति का पता लगाया गया है और उसकी जाँच की गई है।

इस अध्ययन से यह पता चला है कि मानसून के आगमन के संबंध में थिरुवनन्तपुरम और मुम्बई के बीच महत्वपूर्ण संबंध है। थिरुवनन्तपुरम अथवा मुम्बई और आई. एस. एम. आर. के बीच मानसून के आगमन के बारे में किसी महत्वपूर्ण संबंध का पता नहीं चला है। केरल की तुलना में कोंकण में मौसम संबंधी बाढ़ अधिक आती है।

**ABSTRACT.** In this paper, choosing two locations *viz.*, Thiruvananthapuram and Mumbai, an attempt has been made to find whether the onset date of monsoon has any bearing on monsoon rainfall over Kerala and Konkan respectively. Association of the onset dates with Indian Summer Monsoon Rainfall (ISMR) for the country as a whole has also been explored. The study utilizes 100 years' (1901-2000) data.

Homogeneity of the data and other rainfall features have been examined with the help of  $\chi^2$  analysis. Frequency of simultaneous occurrence of droughts and meteorological floods at Kerala and Konkan have been determined and examined.

The study showed that onset over Thiruvananthapuram and Mumbai are significantly related. It revealed absence of any significant relationship between onset over Thiruvananthapuram or Mumbai and the ISMR. Meteorological floods seem to be more frequent over Konkan compared to Kerala.

**Key words** – Monsoon onset, Meteorological flood, Drought.

### 1. Introduction

The southwest monsoon rainfall still continues to be the driving force behind India's economy. Any large-scale negative deviation adversely affects agriculture. The drought, which occurred in 2002, brought down the kharif crop production by nearly 30 million tons from that of 2001.

The southwest monsoon advances first over Kerala around 1<sup>st</sup> June and then slowly progresses northwards. A number of studies between the onset dates and subsequent rainfall have been made in the past (Dhar *et*

*al.*, 1980; Ananthkrishnan and Soman, 1988; Chowdhury *et al.*, 1990; Bansod *et al.*, 1991, etc.) which confirm lack of one-to-one correspondence between date of monsoon onset and rainfall.

In the present study an attempt has been made to determine characteristics of monsoon onset over Thiruvananthapuram and Mumbai and search for association, between them. Correlation between onset of monsoon dates over Thiruvananthapuram (Mumbai) and rainfall over Kerala (Konkan) has also been determined and discussed.

TABLE 1

Statistics of dates of onset over Thiruvananthapuram and Mumbai

Station	Average date	S.D	Earliest onset	No. of occasions of early onset	Mean rainfall on early onset (cm), percent of normal	Most delayed onset	No. of occasions of delayed onset	Mean rainfall on delayed onset (cm), percent of normal	Occasions of normal onset	Mean rainfall (cm) on normal onset and percent of normal
Thiruvananthapuram	1 Jun	7	11 May 1918	23	175, 92%	18 June 1972	28	199, 105%	49	187, 99%
Mumbai	10 Jun	6	24 May 1919	26	266, 98%	25 June 1905, 25 June 1959	24	311, 148%	50	276, 102%

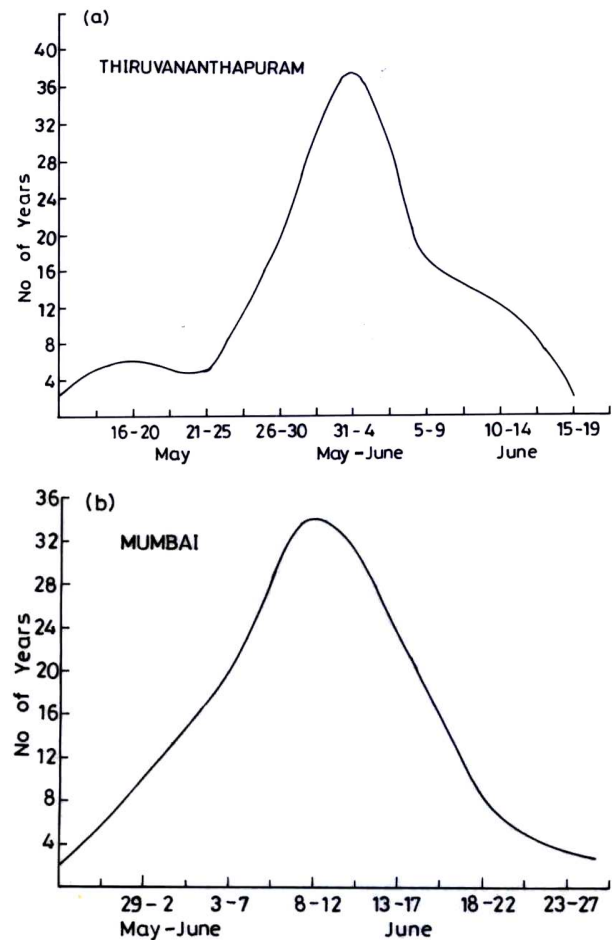
## 2. Data and method of analysis

The study utilizes 100 years' (1901-2000) data on the onset of monsoon over Thiruvananthapuram and Mumbai. Based on pentad (5-day) rainfall, Ananthakrishnan *et al.* (1967) identified onset of monsoon over different locations of India. Subbaramayya *et al.* (1984) used northern limit of monsoon (NLM) to determine onset over the country. Results of studies by Ananthakrishnan *et al.* (1967) on advance of monsoon over Thiruvananthapuram and Mumbai have been re-examined in this study based on the 100 years' data. Monsoon rainfall for 100 years (1901-2000) over Kerala and Konkan have been taken from records of India Met. Deptt. Characteristics of onset over Thiruvananthapuram and Mumbai have been studied through  $\chi^2$  analyses. The onset dates in each year are categorized as early, normal and delayed, depending upon whether it falls on dates  $< \frac{1}{2}\sigma$ , between  $\pm \frac{1}{2}\sigma$  and  $> \frac{1}{2}\sigma$ , from mean dates respectively, where  $\sigma$  is the standard deviation of dates of onset at Thiruvananthapuram and Mumbai. Rainfall over Kerala and Konkan are examined with respect to the onset dates over Thiruvananthapuram and Mumbai respectively, with emphasis on occurrence of drought in these two meteorological sub-divisions. Seasonal rainfall has been categorized as below normal (drought), normal and above normal (or meteorological floods) depending upon whether the departure is  $\leq 26\%$ , within  $\pm 25\%$  and  $\geq 26\%$  of the long period average.

## 3. Results and discussion

### 3.1. Onset dates

The mean date of onset of monsoon over Thiruvananthapuram is found as 1 June (Table 1) with a standard deviation of 7 days. In favourable circumstance it could advance even in May, as it happened in 1918, when monsoon set-in on 11<sup>th</sup> May at Thiruvananthapuram.



**Figs. 1(a&b).** Frequency distribution of onset dates based on 100 years data. (a) Thiruvananthapuram and (b) Mumbai

The most delayed date of onset of monsoon at Thiruvananthapuram is 18<sup>th</sup> June 1972. Both these years are well-documented drought years, the country has faced.

TABLE 2

Frequency distribution of simultaneous occurrence of early, normal and late onset dates over Thiruvananthapuram and Mumbai

		Mumbai			Total
		Early	Normal	Late	
Thiruvananthapuram	Early	14	6	3	23
	Normal	9	29	11	49
	Late	3	14	11	28
	Total	26	49	25	100

The mean date of monsoon onset over Mumbai is found as 10 June with a  $\sigma = 6$  days. In 1919 the monsoon onset occurred earliest in 100 years *i.e.*, on 24<sup>th</sup> May, while in 1905 and 1959 it was delayed the most and advanced only on 25<sup>th</sup> June (Table 1). It is rather surprising to find that the mean dates of onset of monsoon over Thiruvananthapuram and Mumbai determined in this study (based on 100 years' data) are identical with those determined by Ananthakrishnan *et al.* (1967) based on small sample.

The pattern of dates of onset [Fig. 1 (a)] is typically uni-modal at Thiruvananthapuram. On 37% of the years monsoon onset took place between 31<sup>st</sup> May to 4<sup>th</sup> June. Early and late onset of monsoon over Thiruvananthapuram is not an unusual phenomenon. Monsoon has been observed to advance over Thiruvananthapuram unusually on or before 20<sup>th</sup> May, though such incidences are very few (in two years between 11-15 May and 6 between 16-20 May). In 5 years it has occurred between 21<sup>st</sup> to 25<sup>th</sup> May but on 19 occasions it is seen to occur between 26<sup>th</sup> to 30<sup>th</sup> May. Late onset of monsoon is also not uncommon over Thiruvananthapuram. In two years the monsoon onset took place as late as between 15<sup>th</sup> and 19<sup>th</sup> June. In 17% of the occasions the monsoon advanced between 5<sup>th</sup> and 9<sup>th</sup> June, while on 12 occasions between 10<sup>th</sup> and 14<sup>th</sup> June. A late onset of monsoon over Thiruvananthapuram creates a natural anxiety among the people about its future seasonal behaviour over the country. This aspect has been dealt in a separate section below.

The distribution of onset dates over Mumbai appears to follow a normal statistical distribution with maximum concentration between 8<sup>th</sup> to 12<sup>th</sup> June [Fig.1 (b)]. Like Thiruvananthapuram here too early and late onset are both observed. For instance, in two years *viz.*, 1918 and 1925 monsoon advanced between 24<sup>th</sup> and 28<sup>th</sup> May, while on three occasions (1905, 1959 and 1981) the monsoon advance was delayed, and was on 25<sup>th</sup>, 25<sup>th</sup> and 23<sup>rd</sup> June respectively.

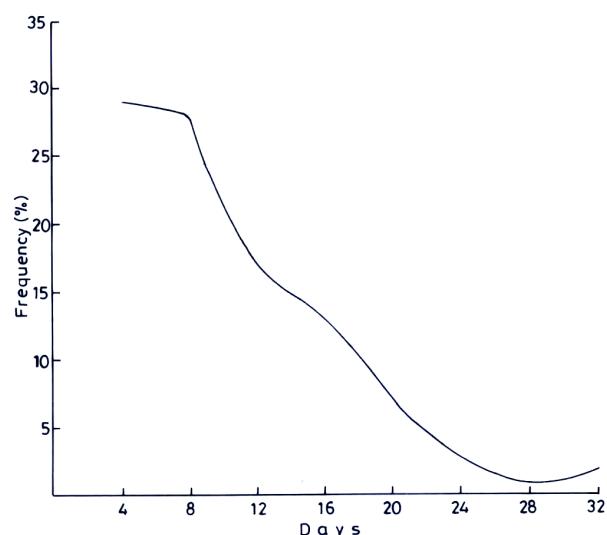


Fig. 2. Frequency distribution of difference of onset dates between Thiruvananthapuram (T) and Mumbai (M) *i.e.*, M - T

### 3.2. Association between onset at Thiruvananthapuram and Mumbai

Normally, it takes about 10-12 days for the monsoon to advance over Mumbai after its arrival over Thiruvananthapuram. The present study shows that in slightly over 50% occasions, the monsoon took up to 8 days to reach Mumbai from Thiruvananthapuram (Fig. 2). There are occasions when it has taken more than 20 days for traversing this distance. In 1959, for instance, it took 25 days for the monsoon to reach Mumbai while in 1956 and 1960 it has taken 29 days each. As mentioned above, favourable synoptic situation often pulls monsoon northwards towards Mumbai and the peninsular India after its arrival over Thiruvananthapuram. If the monsoon current is weak at the time of touching the Kerala coast and remains so for a protracted period, the northward march of monsoon is arrested and the monsoon's northward advance gets unusually delayed. The two cases of abnormal delay (*i.e.*, in 1956 and 1960) in arrival at Mumbai cited above are mainly because of this cause.

TABLE 3

Contingency table showing rainfall statistics of Thiruvananthapuram

		Onset dates over Thiruvananthapuram			Total
		Early	Normal	Late	
Seasonal rainfall over Kerala	BN	6	7	3	16
	N	14	36	21	71
	AN	2	7	4	13
	Total	22	50	28	100

BN : Seasonal rainfall less than -19% of normal.

N : Seasonal rainfall between  $\pm 19\%$ .

AN : Seasonal rainfall more than 19%.

Homogeneity of arrival dates over the two stations and the association between them have been tested by  $\chi^2$  analysis (Table 2). The calculated value of  $\chi^2$  was 21.6 and it exceeded the table value at 5% level of significance. The null hypothesis is thus rejected. It therefore seems that the dates of onset at these stations are homogeneous and that the onset date of monsoon over the two locations has some association between them.

Correlation was worked out for the period 1901-2000 between the onset dates over Thiruvananthapuram and Mumbai. This was found to be 0.49, significant at 1% level of significance. In addition, correlations were also worked out between the two for 50 running years. Thus we worked it out for periods 1901-1950, 1902-1951, etc. These were plotted at the last year of these sub-periods. Result of this analysis is shown in Fig. 3. For first 50 years' data, the correlations between these two appear very large (*i.e.*, 0.71) and significant. Subsequently, from the value of 0.71 the correlations fall to less than 0.5 till 1961. In the later period the correlation increases marginally till 1973 to 0.53 but then decreases gradually. In the last ten years of the last century the correlations seem to have attained a constantly steady value of 0.50.

### 3.3. Onset dates and the sub-divisional rainfall

#### 3.3.1. Onset over Thiruvananthapuram and rainfall over Kerala

Rainfall at a location is often believed to be related to its onset over it. An early onset raises high hopes of good monsoon while its late arrival often causes anxiety and dependency among the masses particularly the farmers. Seasonal rainfall over Kerala and onset over Thiruvananthapuram is examined from two angles *viz.* by working out correlation coefficient between the two and  $\chi^2$  analysis. The correlation between them was found

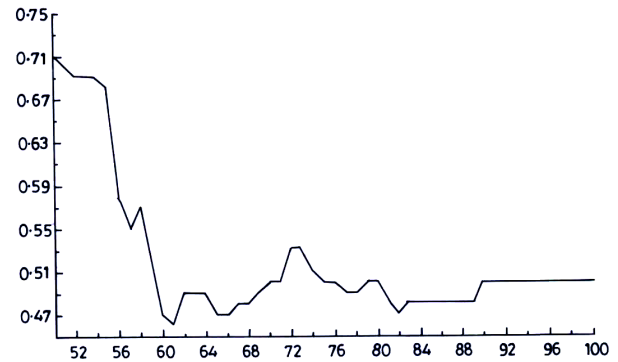


Fig. 3. Year wise correlations between dates of onset of monsoon for 50 years running period at Thiruvananthapuram & Mumbai

negative ( $r = -0.27$ ) but significant (at 5% level of significance). Low correlation between these two was also observed earlier by Bansod *et al.* (1991). Dhar *et al.* (1980) also did not find any significant correlation between monsoon onset over Kerala and rainfall over the west coast for the entire monsoon season.

Dates of onset over Thiruvananthapuram and monsoon rainfall over Kerala when subjected to  $\chi^2$  analysis (Table 3), yielded  $\chi^2$  value of 2.95 which was less than table value of 13.28 (at 5% level of significance). This indicated acceptance of the null hypothesis *i.e.*, the dates of onset of monsoon over Thiruvananthapuram has little bearing on seasonal rainfall over Kerala.

#### 3.3.2. Relationship between onset over Mumbai and rainfall over Konkan

The analysis of onset dates over Thiruvananthapuram and the seasonal rainfall over Kerala, when extended to that over Mumbai and seasonal rainfall over Konkan gave a significant  $\chi^2$  (6.91) (at 5% level of

TABLE 4

Frequencies of occasions (%) of different categories of ISMR with reference to different ranges of onset dates

Onset date	ISMR	Frequency
<b>(a) Thiruvananthapuram</b>		
$\pm 10$ days of normal date of onset	Below normal	15
	Above normal	12
	Normal	51
$> 10$ days of normal date of onset	Below normal	02
	Above normal	02
	Normal	08
$< 10$ days of normal date of onset	Below normal	02
	Above normal	02
	Normal	06
<b>(b) Mumbai</b>		
$\pm 10$ days of normal date of onset	Below normal	15
	Above normal	15
	Normal	61
$> 10$ days of normal date of onset	Below normal	01
	Above normal	01
	Normal	02
$< 10$ days of normal date of onset	Below normal	02
	Above normal	00
	Normal	03

significance). The null hypothesis, like in earlier case, is therefore accepted. We may conclude that onset of monsoon over Mumbai is also not related to the seasonal rainfall over the Konkan coast.

#### 3.4. ISMR and onset over Thiruvananthapuram/Mumbai

Association of Indian summer monsoon rainfall (ISMR), if any, with the onset dates of monsoon over Thiruvananthapuram/Mumbai has also been examined in this paper. In this section, normal ISMR has been extensively referred in the course of discussion. Rajeevan *et al.* (2004) in their classic paper define seasons' rainfall for India as a whole between 90% and 110% of its long period average (LPA) to be normal (*i.e.*, 88 cm). Rainfalls below 90% and above 110% are considered deficient and excess respectively. In view of its versatility, we have also followed the same definition.

As already mentioned, normal date of monsoon advance over Thiruvananthapuram is 1<sup>st</sup> June and has been found to have an interannual variability of 33%. Analysis of variations of onset dates over Thiruvananthapuram and its association with ISMR brings out some interesting features (Table 4). When the monsoon onset occurs over Thiruvananthapuram between  $\pm 10$  days of its normal date of onset it has been noticed

that the ISMR is normal in 51% of the years. In 15% of the cases, the ISMR is below normal when the date of onset is within  $\pm 10$  days of its normal date. ISMR is above normal with nearly same frequency when onset is within  $\pm 10$  days of normal date. Thus in 63% of the cases the ISMR is either normal or above normal with respect to  $\pm 10$  days of normal onset date category at Thiruvananthapuram. As may be seen from the table, when the onset is abnormally delayed or quite early, *i.e.*,  $> 10$  days or  $< 10$  days of normal date, no firm conclusions about the ISMR could be drawn.

The pattern of ISMR with respect to onset date at Mumbai is also given in Table 4. Normally the monsoon advances over Mumbai around 10<sup>th</sup> June. But its variability (*i.e.*, 39%) is slightly higher than that over Thiruvananthapuram. The table suggests that when the advance date of monsoon at Mumbai belongs to the first category (*viz.*,  $\pm 10$  days of normal date), the ISMR is normal in 61% of the cases and above normal in 15% of the cases. In 15% of the years the ISMR could be below normal with respect to this category of onset dates. In nearly 3/4<sup>th</sup> number of years, ISMR could be normal or above normal when the monsoon reaches Mumbai within  $\pm 10$  days of its normal dates of onset. As in the case of Thiruvananthapuram, at Mumbai also an abnormal early or delay of onset does not seem to have much impact over ISMR.

#### 3.5. Association of monsoon rainfall over Kerala/Konkan and ISMR

Possible association between the monsoon rainfall each at Kerala and Konkan and their association with ISMR is also studied. This is done through correlation coefficient analysis.

The correlation of southwest monsoon rainfall over Kerala with ISMR is found as 0.28 and significant (at 5% level of significance). On the other hand, as we move northwards, association of ISMR seems to increase, with the result that rainfall over Konkan bears a highly significant correlation of 0.63, with ISMR. Recently, Padgalwar and Shewale (2003) found that monsoon rainfall over west Rajasthan is strongly correlated with ISMR. Thus, as the monsoon marches northward the sub-divisional rainfall seems to have larger correlation with ISMR.

#### 3.6. Droughts and floods over Kerala and Konkan

Drought and meteorological flood as defined above, are often widespread in areal extent, particularly the former, and simultaneously affect many sub-divisions across the country. In other words, spatial coherence in drought incidence is a reality as was first observed by

Chowdhury *et al.* (1976). In the present study occurrence of drought and floods in monsoon season has been examined.

It is found that Kerala and Konkan faced drought (seasonal rainfall departure  $\leq 26\%$  of normal) on 8 occasions and 7 occasions respectively in the 100 years. But out of these occasions only on one occasion (*i.e.*, 1918) drought was experienced by both the sub-divisions, simultaneously. In other words, probability of occurrence of droughts simultaneously in these two sub-divisions is rather very low.

Out of 8 cases of drought in Kerala, on 4 occasions drought is also observed for the country as a whole; the corresponding figures for Konkan is 6 years out of 7 years of drought.

Kerala experienced floods (seasonal rainfall  $\geq 26\%$  of normal) on 6 occasions while Konkan had floods on 9 occasions showing that Konkan is more prone to floods than Kerala. In addition, out of these occasions of floods, only on two occasions *i.e.*, in 1959 and 1961, floods have occurred in the same year in both Kerala and Konkan. This again shows that probability of simultaneous occurrence of floods in these two meteorological sub-divisions, as in case of droughts, is not very high.

#### 4. Conclusions

(i) The onset dates of monsoon over Thiruvananthapuram and Mumbai bear significant association with each other.

(ii) After first 50 years, the correlations between them seem to have gradually decreased, though remaining statistically significant.

(iii) Dates of onset both at Thiruvananthapuram and Mumbai have little association with seasonal rainfall over Kerala and Konkan respectively.

(iv) When the dates of monsoon onset at Thiruvananthapuram and Mumbai are within  $\pm 10$  days of their normal dates, the chances of normal or above normal ISMR are significantly high.

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