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Hydrological and meteorological features associated with onset of southwest monsoon over Tamil Nadu

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सार – इस शोध पत्र में तमिलनाडु में दक्षिणी पश्चिमी मानसून के आरंभ होने की तारीखों को ज्ञात करने के लिए एक सरल साँख्यिकीय संकल्पना को विकसित किया गया है। 22 वर्षों के आँकड़ों के आधार पर 6 दिनों के मानक विचलन सहित मानसून के आरंभ होने की सामान्य तारीख 4 जून पाई गई है। इससे यह पता चलता है कि तमिलनाडु में मानसून के आरंभ होने की तारीख से वर्षा में हुई मामूली वृद्धि बाद में पहले जैसी नहीं रही और जिससे जून के पूर्वार्द्ध में वर्षा में कमी हुई। इस शोध–पत्र में चेन्नै और कराईकल में 10 वर्षों के दैनिक उपरितन वायु के आँकडों का अध्ययन किया गया है तथा तमिलनाडु में मानसून के आरंभ होने के फलस्वरूप इन प्राचलों के कालिक प्रोफाइलों में आए परिवर्तन को स्पष्ट रूप से बताया गया है। दक्षिणी–पश्चिमी मानसून के विषय में भारत के अन्य मौसम विज्ञान उपखंडों के वर्षा वितरणों की तुलना में तमिलनाडु के मासिक वर्षा वितरण के कुछ विलक्षण अभिलक्षणों पर विचार विमर्श किया गया है।

ABSTRACT. A simple statistical concept has been advanced to determine the onset dates of southwest monsoon over Tamil Nadu. The normal onset date has been found to be 4th June with a standard deviation of 6 days based on 22 years of data. It has been shown that the feeble increase in rainfall over Tamil Nadu in association with the onset is not sustained subsequently and the rainfall decreases in the second half of June. The daily upper air data over Chennai and Karaikal for 10 years have been studied and the change in the temporal profiles of these parameters in response to the monsoon onset over Tamil Nadu has been clearly brought out. Some of the unique features of monthly rainfall distribution of Tamil Nadu *vis-à-vis* those of other meteorological sub-divisions of India in relation to southwest monsoon onset have been discussed.

Key words – Southwest monsoon, Onset, Tamil Nadu, Liquid water content, Upper air wind/temperature, Equatorial trough

1. Introduction

The southwest monsoon season of June-September is the major rainy season for India contributing nearly 75% of its annual rainfall of 115 cm [Based on 100 year date of India Meteorological Department (IMD)]. As such the onset of southwest monsoon bears considerable significance and is a welcome event in India. However for Tamil Nadu located in the southeastern part of peninsular India, the southwest monsoon brings only modest rainfall, especially in the first half. Tamil Nadu, shielded by the western ghats from the moist southwesterly winds during southwest monsoon remains fairly dry in June. In contrast, Kerala, located almost along the same latitudinal belt on the windward side of the ghats, receives copious rains. The southwest monsoon sets in over Kerala around 1 June and thence advances northwards over the peninsular India. (Ananthakrishnan, *et al*. 1967 & Rao, 1976).Till 1990, IMD had not declared onset of southwest monsoon over Tamil Nadu as the general thinking was that southwest monsoon did not set in over the state. Studies related to onset of southwest monsoon over Tamil Nadu have therefore been very few. However, since 1991, IMD has been describing the onset, advance and activity of southwest monsoon over Tamil Nadu. In this note, a simple statistical concept which could determine the onset dates of southwest monsoon over Tamil Nadu (for years prior to 1991) has been advanced. Some of the hydrological and meteorological features associated with the onset have also been studied and the inferences presented.

2. Data

We have made use of the following data in the present study, all obtained from National Data Centre (NDC), Pune of IMD :

(*i*) Monthly sub-divisional rainfall data of IMD obtained from NDC, 1901-2000.

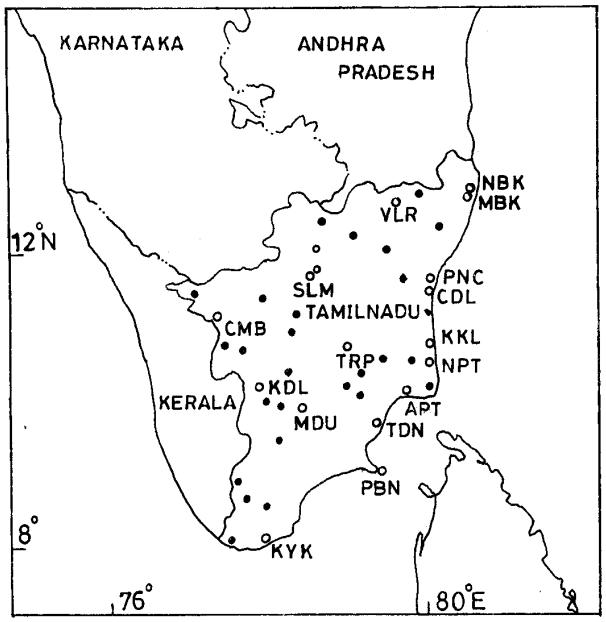

Fig. 1. Spatial distribution of the stations considered in the study

(*ii*) Daily rainfall data of 47 stations of Tamil Nadu for the period 1 May-30 June, 1981-90. Fig. 1 presents the spatial distribution of the stations considered.

(*iii*) Daily upper air and surface data of Chennai (Meenambakkam-MBK) and Karaikal (KKL) for 1 May-30 June, 1981-90. Fig. 1 provides the locations of both these stations.

3. Analysis, results and discussions

3.1. *Variation of normal monthly rainfall vis-à-vis southwest monsoon onset over a few southern sub-divisions*

Fig. 2 presents the normal monthly rainfall for the period April-September for the sub-divisions Kerala, coastal Karnataka, Tamil Nadu and Rayalaseema. (Data based on 1901-2000, sub-divisional rainfall data, IMD). The rainfall from May to June increases from 252 mm to 657 mm over Kerala and from 121 mm to 868 mm over coastal Karnataka. Evidently the sharp increase is in association with the establishment of southwest monsoon. Over Rayalaseema the increase is from 54 mm to 64 mm, but over Tamil Nadu the rainfall from May to June decreases from 73 mm to 62 mm. For both Tamil Nadu and Rayalaseema the second half of the season is rainier than the first half.

However in Kanyakumari district located in the extreme southern parts of Tamil Nadu, off the Arabian Sea - windward side of the western ghats monthly rainfall

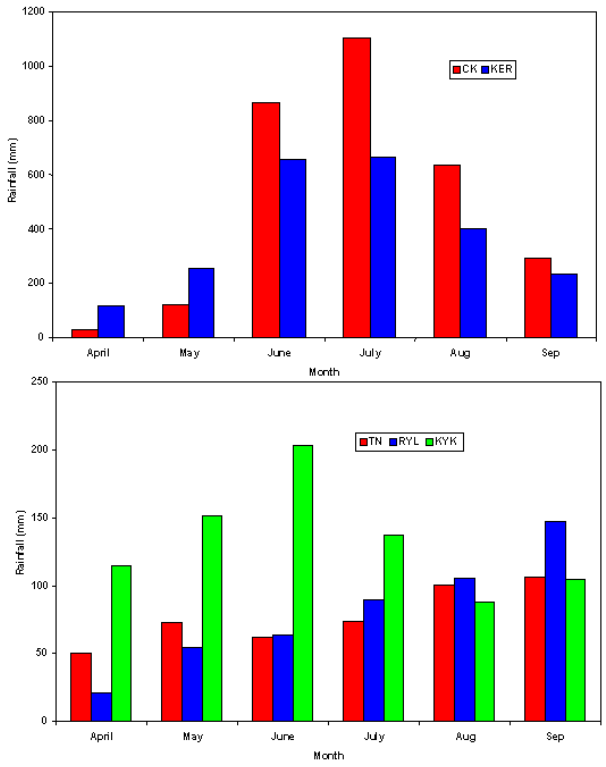

Fig. 2. Normal monthly rainfall distribution (April-September) of Coastal Karnataka (CK), Kerala (Ker), Tamil Nadu (TN), Rayalaseema (RS) and Kanyakumari (KYK) district of Tamil Nadu

distribution similar to that of Kerala is obtained (Fig. 2). All the stations of the above district featured increase of rainfall from May to June , with a few stations receiving normal rainfall of more than 80 cm during June-September (India Met. Dep., 1962 & 2000). In the hilly Nilgiris district, Devala and Gudalur located in the windward side displayed features similar to that of Kerala whereas Coonoor and Kothagiri located in the lee side, manifested normal monthly rainfall pattern similar to that of Tamil Nadu. Shenkottah of Tirunelveli district and Pollachi of Coimbatore district - both located in the gaps of western ghats also manifested increase of rainfall from May to June.

3.2. *Determination of onset dates of southwest monsoon over Tamil Nadu*

3.2.1. *Methodology and determination*

We first propose to advance a methodology to determine the year to year onset dates of southwest monsoon over Tamil Nadu for the pre 1991 period, when IMD did not declare onset over Tamil Nadu. The spatial

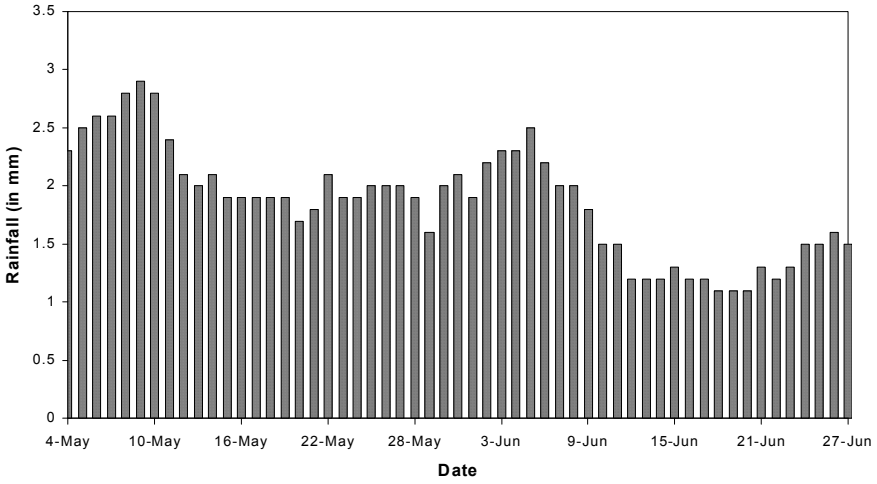

Fig. 3. Normal daily rainfall of Tamil Nadu, May-June

daily rainfall distribution of Tamil Nadu based on the data of 47 stations (Sec.2) was examined for the period 1 May–30 June, 1981-90. After critical study of the pattern of distribution, a methodology to determine the onset of southwest monsoon could be formulated as under :

(*i*) Southwest monsoon should have set in over southern Kerala.

(*ii*) After (*i*) the first day with more than 20% of stations receiving daily rainfall (of atleast 2.5 mm) over Tamil Nadu could be taken as the onset date of southwest monsoon over the state.

The above simple and practical definition is associated with commencement of modest rainfall activity over Tamil Nadu and also maintains consistency with the pattern of monsoon advance from southwest to north. Table 1 presents the dates derived for 1981-90 based on the above method. The benchmark value of 20% was found to be the optimal, for, if this were to be set even slightly higher, onset dates for a few years could not be determined at all. The dates thus derived maintained spatial consistency with the onset dates declared by IMD, over sub-divisions located north of Tamil Nadu also.

Since 1991, IMD has been declaring onset of southwest monsoon over Tamil Nadu every year. Table 1 also presents the IMD declared dates for 1991-2002. The mean dates for 1981-2002 is 4 June with a standard deviation of 5-6 days. The southwest monsoon onset dates over Kerala, as declared by IMD were found to be highly correlated with the dates of Tamil Nadu with a correlation coefficient (CC) of 0.92 based on the 22 year data of 1981-2002, significant at 0.1% level.

TABLE 1

Onset dates of southwest monsoon over Tamil Nadu (1981-2002)

Year	Date	Year	Date
1981	4 June	1992	6 June
1982	3 June	1993	2 June
1983	14 June	1994	2 June
1984	2 June	1995	9 June
1985	3 June	1996	4 June
1986	5 June	1997	10 June
1987	12 June	1998	6 June
1988	2 June	1999	29 May
1989	6 June	2000	2 June
1990	19 May	2001	24 May
1991	3 June	2002	30 May

(1981-90 : determined in the study,
1991-2002: as declared by IMD)

3.2.2. *Normal daily rainfall and superposed epoch analysis*

Fig. 3 presents the smoothed normal daily rainfall of Tamil Nadu computed from the data of the 47 stations during 4 May to 27 June, 1981-90. The maximum daily rainfall of around 2.5 mm is realised during 7-11 May and during 1-8 June. At the time of normal onset the daily rainfall is 2-2.5 mm. Thereafter the daily rainfall decreases reaching 1.1 mm around 19 June and remains below 2 mm up to the end of June. To study the nature of rainfall increase over Tamil Nadu at the time of monsoon onset, superposed epoch analysis of daily rainfall based on the data of 47 stations was performed. For each year

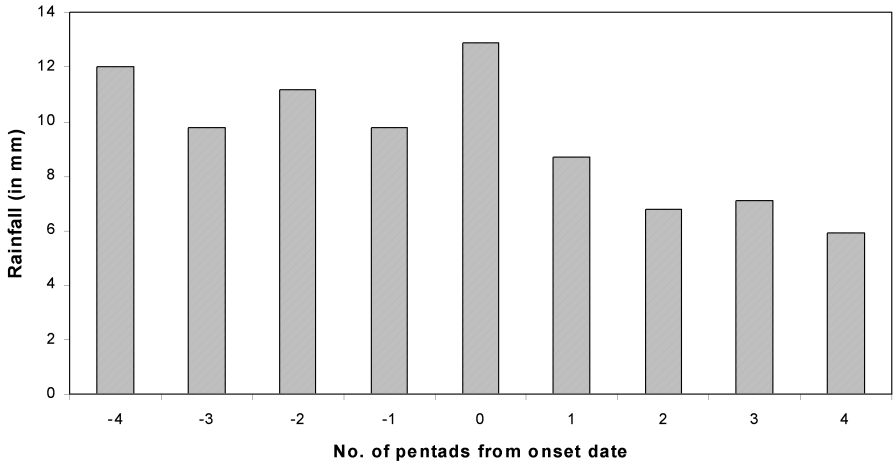

Fig. 4. Mean pentad rainfall over Tamil Nadu with reference to onset of southwest monsoon (0 denotes the pentad commencing from the date of onset)

the pentad with first date as the date of onset was assigned the value 0 and the pentads prior to onset were assigned -1, -2,….. and similarly pentads after onset 1,2,……. The mean rainfall profile was then derived for the -4 to +4 pentads based on the 10 year data, 1981-90, presented in Fig. 4. The pentad rainfall prior to monsoon varies from 6-12 mm and is 13 mm (*i.e.* 2.6 mm per day) during the onset pentad. However thereafter the mean rainfall decreases especially three pentads after onset.

3.2.3. *Change in surface and upper air parameters*

In this section we analyse the changes in temperature and circulation features associated with the advance of southwest monsoon over Tamil Nadu. Figs. 5 & 6 present the mean profiles of temperature and wind for upper levels and surface pressure based on data described in Sec.2 for the different pentads of May-June. The features brought out by the various profiles are briefly discussed now.

The profile of surface pressure resembles a 'U' shaped curve with the minimum pressure realised close to 1 June. The temperature profiles of 850 and 700 hPa levels resemble bell shaped curves with highest temperature recorded in the first pentad of June. At 850 hPa level, zonal winds which are 1-4 m/s westerly during May sharply increase to 10-15 m/s westerly during 1-5 June. However at 700 hPa level zonal winds reverse from easterlies to westerlies during 1-5 June. At 150 hPa level zonal easterlies strengthen during 21-31 May reaching nearly 30 m/s by the end of June. The meridional winds at 150 hPa level reverse from southerly to northerly around 1 June.

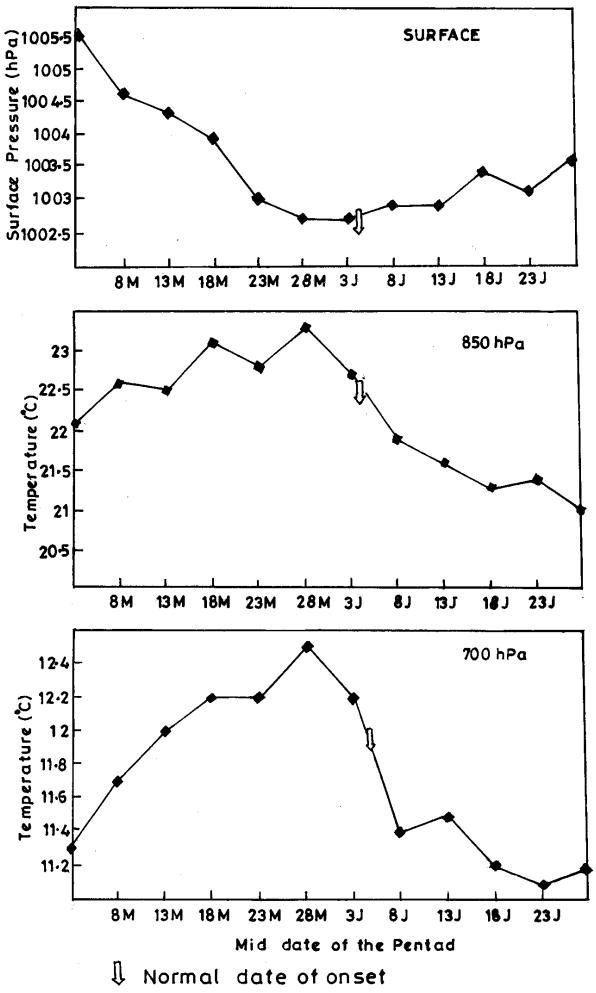

Fig. 5. Pentad mean profiles of surface pressure and upper air temperature, May-June (Mean of Madras and Karaikal)

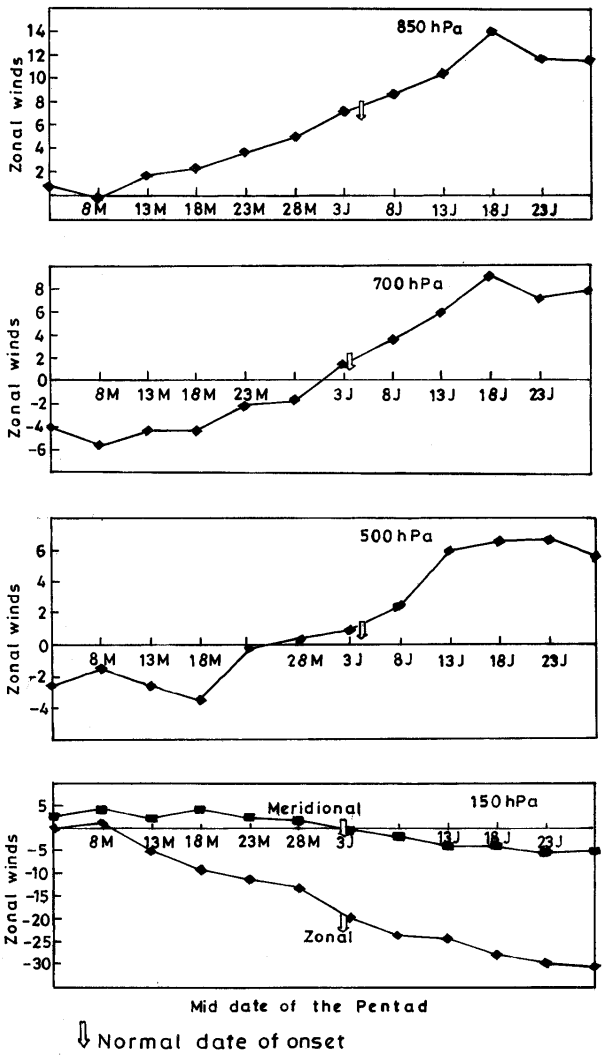

Fig. 6. Pentad mean profiles of zonal and meridional winds (Mean of Madras and Karaikal)

Thus the onset of southwest monsoon over Tamil Nadu is associated with distinct changes in the upper air wind and temperature pattern caused by large scale synoptic features such as south-north movement of equatorial trough over the peninsula and establishment of easterly jet stream at 150 hPa level . These are of course well known facts but clearly documented here using upper air data of Tamil Nadu.

In Table 2 we present the year to year variation of some of the above features by identifying and listing the pentads in which the maxima / minima / discontinuity of the respective parameters appeared. Surface pressure, wind and temperature at 700 hPa level have been included. The CCs between each pentad series with the onset pentad series and the mean pentad are also given. All the pentad series are seen to exhibit good positive

TABLE 2

Variation of pentads corresponding to minimum of surface pressure, maximum of upper air temperature and reversal of zonal winds

Year	Surface pressure minimum	700 hPa temperature maximum	700 hPa zonal wind reversal	Onset over Tamil Nadu
1981	6	6	7	7
1982	7	6	9	7
1983	8	7	10	9
1984	6	6	7	7
1985	5	5	7	7
1986	9	9	9	7
1987	7	7	8	9
1988	6	6	8	7
1989	5	4	8	8
1990	2	3	2	4
Mean	6.1	5.9	7.5	7.2
CC	0.70	0.54	0.84	

Period is given in pentads *viz*., Pentad 1 = 1-5 May; P3 = 11-15 May; P6 = 26-31 May; P7 = 1-5 June; P9 = 11-15 June; P12 = 26-30 June
CC = Correlation Coefficient with onset pentad over Tamil Nadu.

correlation with the onset pentad series. The pressure minimum is attained one pentad before the onset, the temperature maximum is attained 1.2 pentads prior to onset, whereas the 700 hPa level zonal wind reversal occurs 0.4 pentads (2 days) after the onset.

3.2.4. *Liquid water content (LWC) and clouding*

The normal value of vertically integrated LWC over Chennai and Karaikal at 0000 UTC was computed for all the pentads. The LWC values for May and June were almost equal at nearly 53mm and the pentad profile of LWC did not show much variation or sport any rise at the time of onset of southwest monsoon over Tamil Nadu. It is thus evident that the moisture content over Tamil Nadu does not respond to southwest monsoon onset over the state. The amount of normal clouding over Tamil Nadu, based on data of 10 surface observatories (India Met. Dep., 1999) was 4.7 and 5.3 octas for May and June respectively for all types of clouds. Similar figures for low clouds were 1.5 and 1.8 octas respectively. Both types of clouding increased by 10-15% from May-June.

3.3. *Decrease of rainfall over Tamil Nadu after onset – possible reasons*

As seen from Figs 2&3 monthly rainfall over Tamil Nadu slightly decreases from May to June and daily

rainfall manifests a susceptible decrease after onset, within June. This is despite the establishment of monsoon air mass over the peninsula, the continued availability of large amount of LWC in the atmosphere and the slight increase in clouding in June. A plausible ascription for this somewhat discordant feature could be advanced thus. In Tamil Nadu during and after the onset phase of southwest monsoon, the existence of east-west trough present in the 700-500 hPa layer during the onset phase could generate higher vertical velocity and consequently some increase in rainfall for a brief period. Once the above trough moves further northwards in association with the northward advance of southwest monsoon, the vertical velocity thus generated should decrease. Further with the establishment of strong low level jet in the monsoon westerlies located along 13-15º N over the peninsula, negative shear vorticity prevails in the lower troposphere over Tamil Nadu. The above features are obviously, the major factors behind the decrease of rainfall after onset.

4. Summary

The results of the study are summarised as given below :

(*i*) In Tamil Nadu, rainfall decreases from May to June despite the onset of southwest monsoon in the first week of June. However onset similar to that over Kerala is observed in Kanyakumari district, parts of Nilgiris district and a few other individual stations with a noticeable rise of rainfall from May to June. The normal onset date of southwest monsoon over Tamil Nadu for 1981-2002 is 4 June with a standard deviation of 6 days.

(*ii*) A simple statistical method to determine onset dates of southwest monsoon over Tamil Nadu, for years when India Meteorological Department did not declare onset over the state, has been advanced. This method yielded spatially consistent onset dates for the period 1981-90.

(*iii*) The normal daily rainfall for the period 1 May - 30 June and the analysis based on superposed epoch technique have shown that the feeble increase of rainfall over Tamil Nadu at the time of southwest monsoon onset, is not sustained and rainfall decreases in the second half of June.

(*iv*) The pentad surface pressure over Tamil Nadu decreases from May, reaches minimum one pentad before onset and then rises. The temperature over 700 hPa rises from May, reaches maximum 1.2 pentads (6 days) before onset and decreases. The 700 hPa wind reverses from easterly to westerly 2-3 days after onset.

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References

Anantha Krishnan, R., Acharya, V. R. and Ramakrishnan, A. R., 1967, "On the criteria for declaring the onset of southwest monsoon over Kerala", India Met. Dep., FMU Report No. 1.

India Met. Dep., 1962, Monthly and annual normals of rainfall and rainy days.

India Met. Dep., 1999, Climatological tables of observatories in India - 1951-1980.

India Met. Dep., 2000, Climate of Tamil Nadu.

Rao, Y. P., 1976, "Southwest monsoon, Met. Monograph", India Met. Dep.