

Variability of southwest monsoon over Rajasthan and Kerala

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सार – इस शोध-पत्र में गत 63 वर्षों (1941–2003) के आँकड़ों के आधार पर पूर्वी और पश्चिमी राजस्थान के उपखंडों में दक्षिणी-पश्चिमी मानसून ऋतु के आरम्भ और उसकी वापसी की तारीखों की जाँच की गई है। इस जाँच का उद्देश्य इन प्राचलों द्वारा राजस्थान में दक्षिणी-पश्चिमी मानसून का पूर्वानुमान लगाने के लिए इनकी परिवर्तनशीलता और प्रवृत्ति के कुछ प्रमुख पहलुओं का पता लगाना है। इससे संबंधित विभिन्न अंतः सहसंबंध गुणांक तैयार किए गए हैं। इस अध्ययन से यह पता चला है कि मानसून की गतिविधि में परिवर्तन मानसून की अवधि में बढ़ोतरी, समय से पहले मानसून का आरम्भ होने और देर से इसकी वापसी के फलस्वरूप राजस्थान में मानसून की अवधि और मौसमी वर्षा में वृद्धि होती है। यदि पूर्वी राजस्थान में मानसून निर्धारित समय से पहले आता है तो निश्चित रूप से पश्चिमी राजस्थान में भी समय से पहले आ जाता है।

ABSTRACT. The onset, withdrawal dates and rainfall of southwest monsoon corresponding to east and west Rajasthan sub-divisions have been examined statistically for the past 63 years (1941-2003) to bring out some major aspects of their variability and trend to predict these parameters of southwest monsoon over Rajasthan. Various correlation coefficients have been worked out. Study reveals, shift in monsoon activity, enhancement of monsoon duration, early onset and late withdrawal enhances monsoon duration and seasonal rainfall over Rajasthan. Early onset over east Rajasthan certainly brings early onset over west Rajasthan.

Key words – Correlation coefficient (CC), Standard deviation (SD), Coefficient of variation (CV).

1. Introduction

Southwest monsoon rainfall is the principal rain bringing season for whole of India except Tamil Nadu which accounts for about 80% of annual rainfall. Monsoon rainfall influence the crop production and has a dramatic impact on the Indian economy as well as the living conditions of the inhabitants of the country as a whole.

India Meteorological Department has been issuing long range forecast of rainfall for southwest monsoon for “country as a whole” for over a century by now. However, demand for long range forecast for southwest monsoon with increased special and temporal resolution has been on the increase during past few years. Therefore it is of interest to examine the variability of various features of southwest monsoon on regional scale.

In the continent southwest monsoon normally sets in over Kerala coast around first June and reaches east Rajasthan around 29th June, covering the whole state of Rajasthan and thereby entire country by 15th July. The

withdrawal of monsoon starts from 1st September from west Rajasthan and within fifteen days the state becomes free from monsoon rain. Thus the duration of southwest monsoon rainfall over the state is practically from 29th June to 15th September *i.e.*, about 80 days annually.

Rajasthan is a state of least rainfall where the monsoon sets in the last but begins to withdraw early, and so observes relatively less monsoon duration and receives 75 to 80 % of its annual rainfall during the monsoon season. Therefore, the temporal and spatial distribution of rainfall has considerable importance for management of water resources and agricultural yields, particularly in dry farming. The feature of variability of onset, withdrawal and duration of monsoon will certainly help the agriculturist, farmers, planners of the country, various users and also facilitate weather forecasters.

Dates of monsoon onset and its associated features have been studied by Bhullar (1952), Ananthkrishnan *et al.* (1967) and Subramayya *et al.* (1984). Dhar *et al.* (1980) found that quantum of rainfall during monsoon season does not have any association with onset dates.

TABLE 1(a)

Dates of onset, withdrawal, monsoon duration & associate rainfall

S. No.	Year	Dates of onset			Dates of withdrawal		Duration		Rainfall (mm)	
		Kerala	E-Raj	W-Raj	E-Raj	W-Raj	E-Raj	W-Raj	E-Raj	W-Raj
1	1941	23 May	07 Jun	11 Jun	22 Sep	20 Sep	107	101	363	203
2	1942	10 Jun	15 Jul	16 Jul	15 Oct	01 Oct	92	77	755	216
3	1943	29 May	15 Jul	15 Jul	01 Oct	25 Sep	78	72	577	332
4	1944	03 Jun	26 Jul	04 Aug	12 Oct	27 Sep	78	54	655	787
5	1945	05 Jun	01 Jul	25 Jul	25 Oct	10 Oct	116	78	876	347
6	1946	29 May	26 Jun	29 Jun	22 Sep	19 Sep	88	82	978	246
7	1947	03 Jun	23 Jul	04 Aug	21 Sep	17 Sep	60	44	843	254
8	1948	11 Jun	14 Jul	20 Jul	21 Sep	13 Sep	69	55	729	206
9	1949	23 May	09 Jul	14 Jul	01 Oct	23 Sep	76	79	564	290
10	1950	27 May	10 Jul	10 Jul	23 Sep	21 Sep	75	73	808	328
11	1951	31 May	01 Jul	04 Jul	15 Sep	12 Sep	76	70	330	221
12	1952	20 May	16 Jul	23 Jul	15 Oct	01 Oct	91	70	782	269
13	1953	07 Jun	10 Jul	16 Jul	15 Oct	08 Oct	97	84	490	295
14	1954	31 May	25 Jun	09 Jul	04 Oct	03 Oct	101	86	678	274
15	1955	29 May	21 Jun	12 Aug	21 Oct	06 Oct	122	55	851	330
16	1956	21 May	08 Jun	10 Jun	17 Sep	12 Sep	101	94	767	354
17	1957	01 Jun	10 Jul	11 Jul	18 Sep	11 Sep	70	62	597	182
18	1958	14 Jun	02 Jul	09 Jul	25 Sep	24 Sep	85	77	689	241
19	1959	31 May	01 Jul	08 Jul	16 Oct	14 Oct	107	98	766	427
20	1960	14 May	22 Jun	29 Jun	08 Sep	04 Sep	78	67	571	194
21	1961	18 May	10 Jun	21 Jun	18 Oct	02 Oct	130	103	779	398
22	1962	17 May	24 Jun	05 Jul	27 Sep	26 Sep	95	83	589	240
23	1963	31 May	10 Jul	14 Jul	27 Sep	18 Sep	71	66	645	166
24	1964	06 Jun	05 Jul	06 Jul	29 Sep	28 Sep	86	84	649	336
25	1965	26 May	10 Jul	14 Jul	27 Sep	18 Sep	79	63	370	150
26	1966	01 Jun	06 Jul	06 Jul	29 Sep	20 Sep	76	85	392	203
27	1967	09 Jun	02 Jul	02 Jul	21 Sep	21 Sep	81	81	698	262
28	1968	08 Jun	09 Jul	09 Jul	30 Aug	30 Aug	52	52	470	116
29	1969	17 May	14 Jul	15 Jul	25 Sept	17 Sep	73	64	604	110
30	1970	26 May	01 Jul	03 Jul	05 Oct	29 Sep	96	88	739	310
31	1971	27 May	26 Jun	02 Jul	20 Sep	13 Sep	79	80	756	181
32	1972	18 Jun	26 Jun	30 Jun	06 Sep	06 Sep	72	68	359	187
33	1973	04 Jun	05 Jul	06 Jul	28 Sep	12 Sep	85	68	809	384
34	1974	27 May	11 Jul	12 Jul	10 Sep	04 Sep	71	54	503	136
35	1975	31 May	23 Jun	30 Jun	11 Oct	23 Sep	110	85	543	578
36	1976	31 May	11 Jul	15 Jul	22 Sep	19 Sep	83	66	737	416
37	1977	31 May	29 Jun	30 Jun	26 Sep	23 Sep	89	85	760	400
38	1978	28 May	22 Jun	03 Jul	18 Sep	11 Sep	88	70	845	415
39	1979	11 Jun	11 Jul	15 Jul	21 Sep	16 Sep	72	63	476	282
40	1980	01 Jun	26 Jun	28 Jun	23 Sep	12 Sep	89	76	545	200
41	1981	30 May	29 Jun	10 Jul	03 Oct	03 Sep	96	55	678	197
42	1982	30 May	14 Jul	22 Jul	15 Sep	03 Sep	63	43	410	200
43	1983	13 Jun	04 Jul	18 Jul	20 Sep	19 Sep	77	64	645	366
44	1984	01 Jun	03 Jul	06 Jul	24 Sep	22 Sep	83	78	584	238
45	1985	28 May	14 Jul	14 Jul	19 Sep	11 Sep	67	59	500	214
46	1986	04 Jun	24 Jun	24 Jul	08 Oct	17 Sep	106	55	519	166
47	1987	02 Jun	15 Jul	27 Jul	19 Sep	12 Sep	66	47	314	99
48	1988	26 May	30 Jun	01 Jul	30 Sep	12 Sep	92	73	483	250
49	1989	03 Jun	01 Jul	02 Jul	04 Oct	04 Oct	95	94	392	226
50	1990	19 May	28 Jun	01 Jul	01 Oct	28 Sep	95	89	693	473
51	1991	02 Jun	16 Jul	19 Jul	21 Sep	18 Sep	67	61	455	183
52	1992	05 Jun	12 Jul	14 Jul	20 Sep	17 Sep	70	65	630	460
53	1993	27 May	27 Jun	05 Jul	01 Oct	21 Sep	96	78	673	342
54	1994	28 May	27 Jun	30 Jun	21 Sep	19 Sep	86	81	815	479
55	1995	08 Jun	13 Jul	13 Jul	21 Sep	15 Sep	70	64	750	432
56	1996	03 Jun	22 Jun	24 Jun	17 Sep	17 Sep	87	85	890	430
57	1997	09 Jun	09 Jul	19 Jul	28 Sep	18 Sep	81	61	642	409
58	1998	02 Jun	30 Jun	30 Jun	29 Sep	28 Sep	91	90	628	281
59	1999	25 May	22 Jun	12 Jul	26 Sep	21 Sep	96	71	552	213
60	2000	01 Jun	30 Jun	02 Jul	23 Sep	13 Sep	85	73	438	219
61	2001	23 May	24 Jun	03 Jul	14 Sep	10 Sep	82	69	521	251
62	2002	29 May	19 Jul	15 Aug	20 Sep	16 Sep	63	32	262	86
63	2003	08 Jun	05 Jul	05 Jul	30 Sep	19 Sep	87	76	590	352

TABLE 1(b)

Associate characteristic of Southwest monsoon

Period		Onset			Withdrawal		Duration		Rainfall (cm)	
		Kerala	E-Raj	W-Raj	E-Raj	W-Raj	E-Raj	W-Raj	E-Raj	W-Raj
1941-2003	Mean	31 May	03 Jul	10 Jul	26 Sep	20 Sep	85	71	62.2	28.6
	S.D.	7	10	12	11	9	15	15	16.4	12.5
	Earliest	14 May	07 Jun	10 Jun	30 Aug	30 Aug	52	32	26.2	8.6
		1960	1941	1956	1968	1968	lowest in 1968	lowest in 2002	lowest in 2002	lowest in 2002
Most Delayed	18 Jun	26 Jul	15 Aug	25 Oct	14 Oct	130	103	97.8	78.7	
	1972	1944	2002	1945	1959	highest in 1961	highest in 1961	highest in 1946	highest in 1944	
1941-1970 (1 st slot)	Mean	30 May	03 Jul	10 Jul	30 Sep	23 Sep	88	74	65.3	27.6
	S.D.	8	12	13	13	10	17	15	16	13
1971-2000 (2 nd slot)	Mean	02 Jun	03 Jul	09 Jul	24 Sep	16 Sep	83	69	60.7	30.2
	S.D.	5	8	9	8	7	13	13	16	13

Pant and Hingane (1998) found slight increase in monsoon rainfall, inspite of the large variability in the arid zone. In this paper results of analysis of onset, withdrawal, duration and rainfall over Rajasthan (extreme northwest frontier) from 1941 to 2003 are presented and statistically examined including the onset dates over Kerala (extreme southern tip). In addition, it is proposed to examine whether onset dates and monsoon duration have any relationship with monsoon rainfall.

2. Data

The actual dates of onset (withdrawal) of monsoon over east Rajasthan, west Rajasthan and Kerala and rainfall data were extracted from the Weekly and Daily Weather Reports published by the India Meteorological Department for the recent 63 years period (1941-2003). For east and west Rajasthan the onset dates thus collected are the dates when monsoon has set in over the entire region. The duration of monsoon has been calculated by getting the difference between onset and withdrawal dates.

3. Results & discussion

Tables 1(a&b) presents the dates of onset (withdrawal), monsoon duration, seasonal rainfall and their associate characteristics. Analysis and computation based on the data for the period 1941-2003 including

decadal and two 30 years blocks of data from 1941-70 & 1971-2000 reveals the following.

3.1. Onset of southwest monsoon

(i) For east Rajasthan

Mean date : 3rd July, S. D : 10 days, range : 7 June to 27 July

(ii) For west Rajasthan

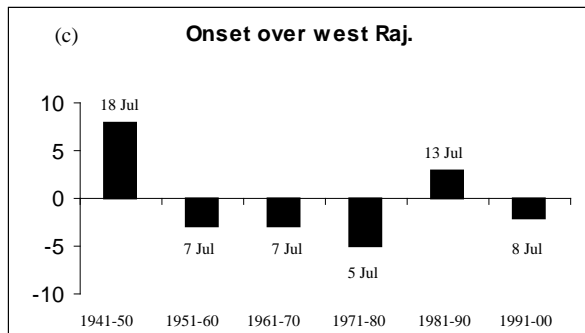
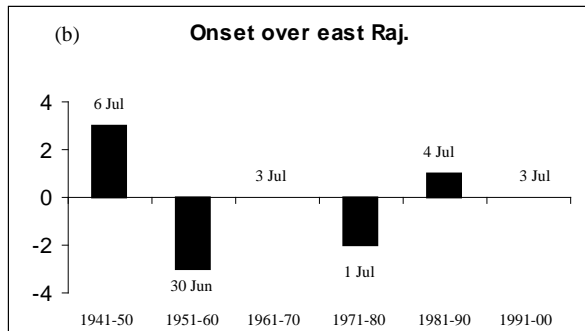
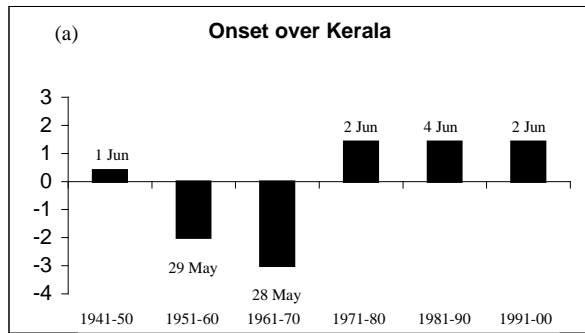
Mean date : 10th July, S. D : 12 days, range : 11 June to 15 August

(iii) For Kerala

Mean date : 31st May, S. D : 7 days, range : 14 May to 18 June

3.1.1. Difference of onset dates between Kerala and east (west) Rajasthan

After onset over Kerala, normally after 33 (40) days onset occurs over east (west) Rajasthan with S. D 10 (12) days and Range : east (west) Rajasthan are 13 – 58 (17 – 78) days.



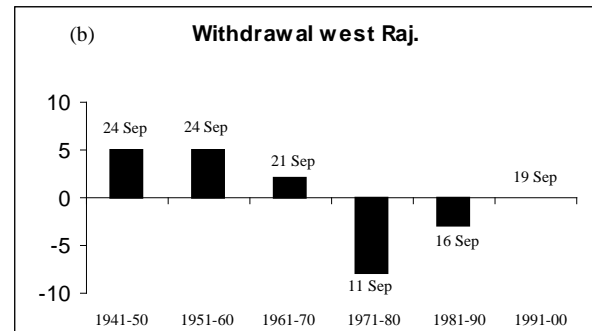
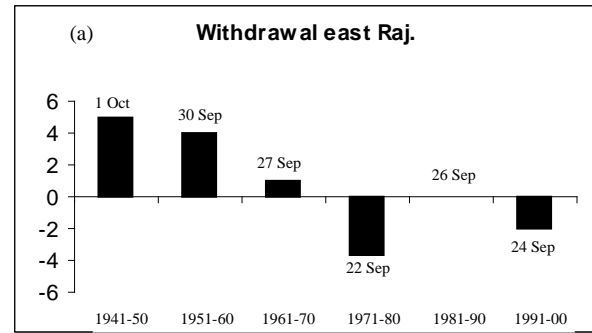
Figs. 1(a-c). Decadal mean fluctuations of monsoon onset (a) Kerala, (b) east Rajasthan and (c) west Rajasthan

3.1.2. Variability

(i) Table 1 reveals that over Kerala during first 30 years slot mean onset is 1 day earlier and 2 days later during second 30 years slot while for west Rajasthan it is one day earlier in second slot as compared to 63 years mean dates.

(ii) The variability during first slot is higher than the second slot.

(iii) Figs. 1(a-c) reveal that the lowest decadal mean is found in 70s in Kerala and in 60s (80s) in east (west) Rajasthan. The highest variability is found in the 50s in Rajasthan and in Kerala it was in 60s & 70s, the decadal



Figs. 2(a&b). Decadal mean fluctuations of withdrawal of monsoon over (a) east Rajasthan and (b) west Rajasthan

variability from 60s and onwards is lower than the long period variability and the amplitude of variability over west Rajasthan is highest.

3.2. Withdrawal of southwest monsoon

(i) For east Rajasthan

Mean date : 26th September, S. D : 11 days, range : 30th August to 25th October

(ii) For west Rajasthan

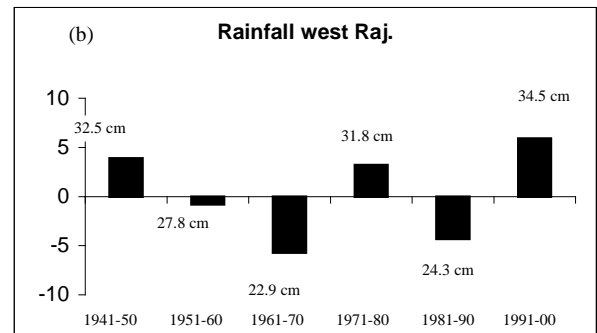
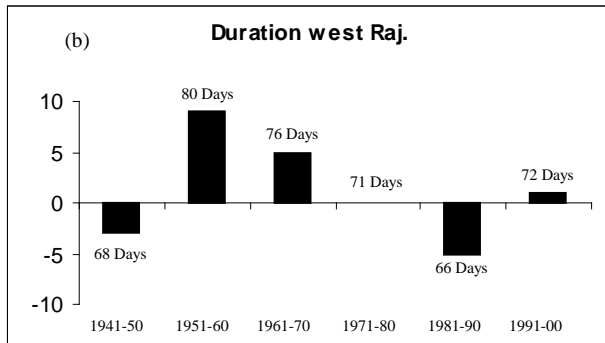
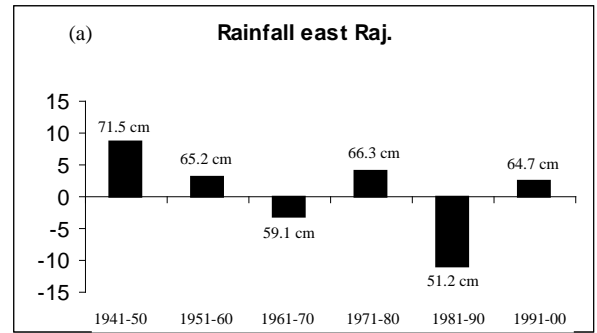
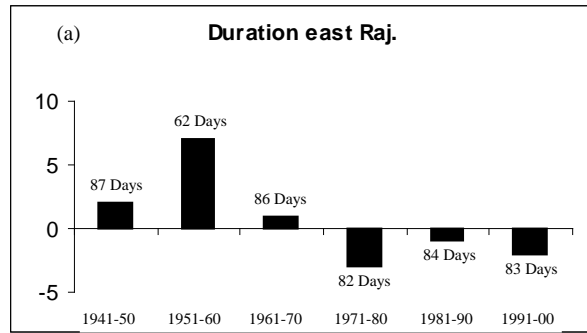
Mean date : 19th September, S. D : 9 days, range : 30th August to 14th October

3.2.1. Variability

(i) The mean dates of withdrawal are observed later than the existing normal dates for Rajasthan.

(ii) The mean values are lower in second 30 years slot in Rajasthan than first 30 years slot.

(iii) Figs. 2(a&b) reveal that the decadal mean was found highest in 50s and lowest in 80s in Rajasthan, the



Figs. 3(a&b). Decadal mean duration of monsoon over (a) east Rajasthan and (b) west Rajasthan

Figs. 4(a&b). Decadal mean seasonal rainfall over (a) east Rajasthan and (b) west Rajasthan

highest variability was observed in 60s while lowest in 1991-2000 and the variability in the mean date has been lower in second 30 years slot

3.3. *Duration of southwest monsoon*

(i) For east Rajasthan

Mean : 85 days, S. D : 15 days, Range : 52 to 130 days

(ii) For west Rajasthan

Mean : 71 days, S. D : 15 days, Range : 32 to 103 days

3.3.1. *Variability*

(i) The mean duration and variability are found higher in first slot.

(ii) Figs. 3(a&b) reveal that the lowest decadal mean duration has been found in 80s in east Rajasthan and in 50s in west Rajasthan while highest in the 60s and the lowest variability occurred in the decade 1991-2000 and the highest was in 50s.

3.4. *Rainfall*

(i) For east Rajasthan

Mean : 62.2 cm, S. D : 16.4 cm, C.V. : 26%, Range : 26.2 cm to 97.8 cm.

(ii) For west Rajasthan

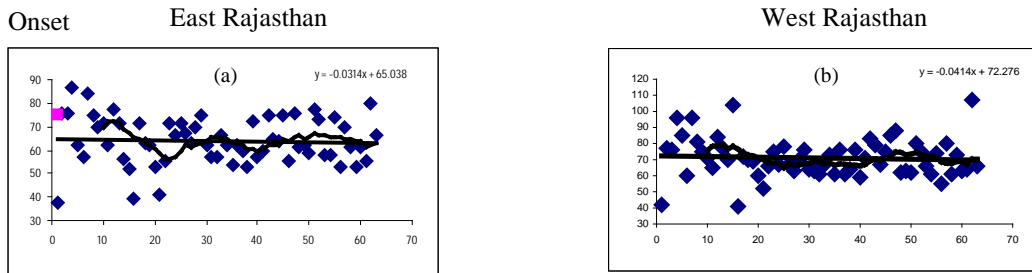
Mean : 28.6 cm, S. D : 12.5 cm, C.V. : 44%, Range : 8.6 cm to 78.7 cm.

3.4.1. *Variability*

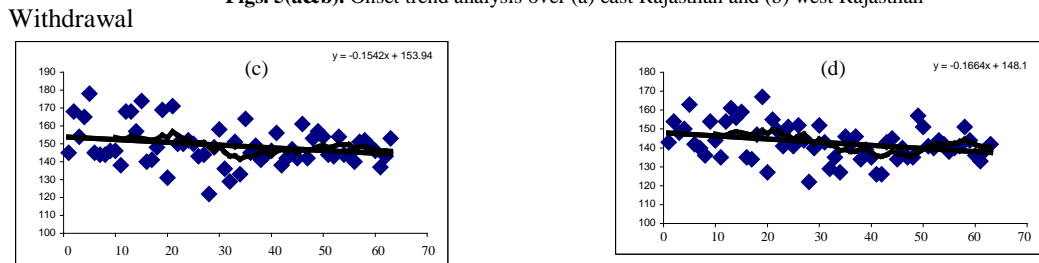
(i) The mean values is found higher in first 30 years slot in east Rajasthan while it is in second slot in west Rajasthan. However, there is consistent pattern of variability in both these slots over both these sub-divisions of Rajasthan.

(ii) Figs. 4(a&b) reveal that the lowest decadal mean over east (west) Rajasthan was in 90s (70s) while highest values in 50s (1991-2000) and the variability was highest in 50s and lowest in 90s over Rajasthan.

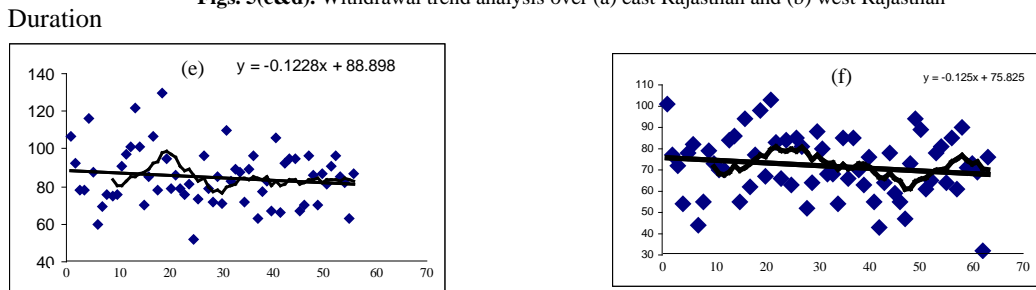
Trend analysis



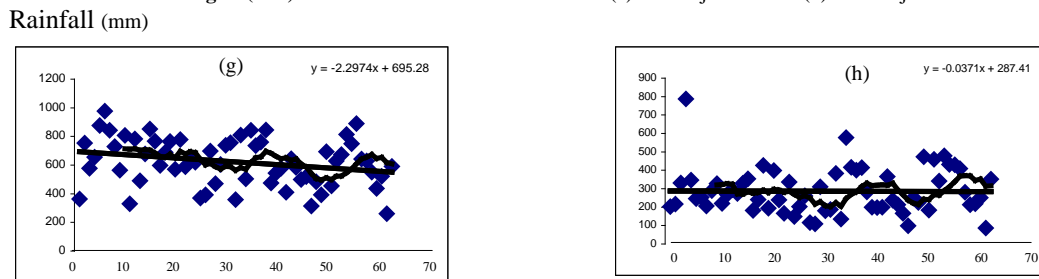
Figs. 5(a&b). Onset trend analysis over (a) east Rajasthan and (b) west Rajasthan



Figs. 5(c&d). Withdrawal trend analysis over (a) east Rajasthan and (b) west Rajasthan



Figs. 5(e&f). Trend in duration of monsoon over (a) east Rajasthan and (b) west Rajasthan



Figs. 5(g&h). Trend in seasonal rainfall over (a) east Rajasthan and (b) west Rajasthan

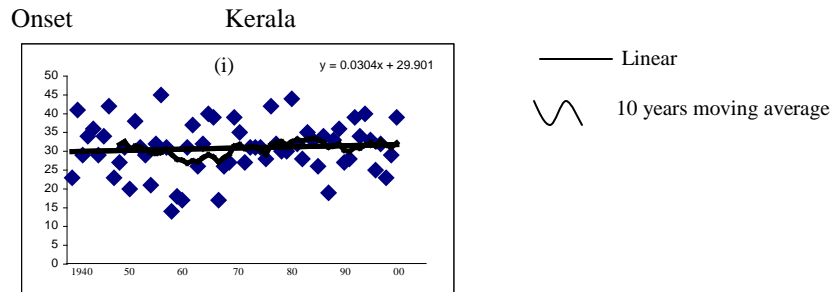


Fig. 5(i). Trend in onset over Kerala

TABLE 2
Correlation Coefficients(CC) for the period 1941-2003

Functions	Serial number of functions								
	1	2	3	4	5	6	7	8	9
1. Kerala onset	1.00								
2. East Rajasthan onset	0.37**	1.0							
3. West Rajasthan onset	0.26**	0.71*	1.0						
4. East Rajasthan withdrawal	-0.02	-0.02	0.24	1.0					
5. West Rajasthan withdrawal	-0.002	-0.03	0.11	0.79*	1.0				
6. East Rajasthan duration	-0.26	-0.68*	-0.30	0.74*	0.60*	1.0			
7. West Rajasthan duration	-0.22	-0.62*	-0.76*	0.31	0.56*	0.64*	1.0		
8. East Rajasthan rainfall	-0.01	-0.19	-0.10	0.36*	0.33*	0.39*	0.30*	1.0	
9. West Rajasthan rainfall	0.08	-0.07	-0.09	0.38*	0.36*	0.33*	0.30*	+0.59*	1.0

* Significant at 5% level and ** Significant at 1% level
 Decadal mean values of onset (Fig. 1), withdrawal (Fig. 2) and duration (Fig. 3) and rainfall (Fig. 4) of Southwest Monsoon.

3.5. Trend analysis

Fluctuations in onset, withdrawal, duration and seasonal rainfall along with the linear trend and 10-years moving average are depicted in Figs. 5(a-i). It reveals slight decreasing trend in these parameters over Rajasthan and slight increasing trend in onset over Kerala. However, no significant trend could be established.

4. Relation based on correlation analysis

Correlation coefficients (CC) between various dates of series have been computed and found significant mostly at 1% level and presented in matrix form in Table 2. The following points emerge :

- (i) Early onset over Kerala have chance to cause early onset over east (west) Rajasthan [+0.37 (+0.26)].
- (ii) Early onset over east Rajasthan certainly brings early onset over west Rajasthan (+0.71).
- (iii) Early onset over east (west) Rajasthan enhances monsoon duration [-0.70 (-0.77)].

(iv) Early (late) onset favours good (poor) monsoon rainfall for the period 1971-2003 was observed [-0.47 (-0.43)] for east (west) Rajasthan.

(v) Early withdrawal over west Rajasthan followed by early withdrawal over east Rajasthan (+0.79).

(vi) Early withdrawal gives rise to less monsoon duration over east (west) Rajasthan [+0.74 (+0.56)] and less monsoon rainfall [+0.36 (+0.36)].

(vii) Higher monsoon duration over east Rajasthan favours higher monsoon duration over west Rajasthan (0.64).

(viii) Higher monsoon duration attributes to higher monsoon rainfall both over east (+0.39) & west (+0.33) Rajasthan.

(ix) Good rainfall over east Rajasthan results in good rainfall over west Rajasthan (+0.59).

(x) Early onset does not govern early withdrawal.

5. Conclusion

The following points emerge by the analysis of the data for the period 1941-2003.

(i) The mean onset date is found one day earlier over Kerala, four days later (five days earlier) over east (west) Rajasthan while withdrawal mean date was 11 (19) days later over east (west) Rajasthan as compared to the existing normal date. It indicates shift in monsoon activity and enhancement of monsoon duration over Rajasthan.

(ii) The variability during 1941-70 over Rajasthan was higher in onset, withdrawal and duration as well as over Kerala onset.

(iii) There is consistent pattern of variability in seasonal rainfall over Rajasthan.

(iv) Analysis shows slight decreasing trends in onset, withdrawal, rainfall and duration over Rajasthan and slight increasing trend in onset over Kerala (Fig. 5)

(v) Early onset and late withdrawal enhances monsoon duration and rainfall over Rajasthan.

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