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Periodicities in the dates of onset of the southwest monsoon over Kerala

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ABSTRACT. A Burg (MEM) spectrum analysis of the dates of onset of the SW monsoon over Kerala as given (*a*) IMD, (*b*) Ananthakrishnan *et al.* (1967) and (*c*) Ramdas *et al.* (1954) revealed periodicities of about T_k= 2.3, 2.8, 3.5, 3.9, 4.7, 5.5, 6.2, 7.3, 8.5, 10.8, 14, 20 and 40 years with amplitudes of about 2-5 days. When used for prediction, the match was within ± 5 days for the series of Ananthakrishnan *et al.* (1967) and within ± 10 days for the IMD series and the series of Ramdas *et al.* (1954).

1. Introduction

The normal date of onset of the southwest monsoon over Kerala is 1 June. However, this date differs considerably from year to year and, in the last few decades, has shown dispersion between 7 May and 18 June, as seen from the weather records of the IMD (India Meteorological Department). There seems to be a considerable amount of subjectiveness involved in the fixing of this onset date. Apart from the IMD official list of the "Dates of onset" for the last several decades, Ramdas *et al.* (1954) have worked out "dates of Establishment" of the monsoon over the Travancore Cochin area year by year for 1891-1950. Recently, Ananthakrishnan *et al.* (1967) examined very critically the criteria for declaring the monsoon onset and, in view of the great subjectivity involved in the present day official procedure of fixing the dates of onset, recommended a set of general conventions and empirical rules for declaring the onset and recession of the monsoon over Kerala. They also gave a new list of the dates of onset of monsoon fixed on the basis of these objective rainfall criteria. Table 1 lists the official IMD dates of onset, the dates given by Ramdas *et al.* (1954) and also the dates given by Ananthakrishnan *et al.* (1967). The dates of Ramdas *et al.* (1954) are in general *earlier* than the IMD dates, on the average by about 5 days, while those of Ananthakrishnan *et al.* (1967) are within ± 3 days of the IMD dates in about 60 per cent cases. However, in some years, IMD dates differ from the others by more than 10 days.

2. Periodicities

Are these year-to-year changes just random or are there any periodicities involved? We propose to examine this aspect by converting these dates into a time series designating May 1, 2, . . . 31 as 1 to 31 and June 1, 2, . . . 30 as 32, 33, . . . 61, and subjecting these series to a power spectrum analysis by the MEM (Maximum Entropy Method) evolved by Burg (1972 and earlier references given therein). A computer program for such an analysis is given by Anderson (1974) and a critical review of MEM is given by Ulrych and Bishop (1975). Burg (MEM) spectra can be obtained for various LPEF (Lengths of the Prediction Error Filter). At low LPEF, (about 10 per cent of the length of the data series), only high frequencies are resolved. For lower frequencies, higher and higher LPEF are needed, sometimes upto 90 per cent of the data length; but at such high LPEF, high frequency peaks show splitting. As a general presciption, Ulrych and Bishop (1975) recommend an LPEF of about half data length, (LPEF=30 for a 60 point data series). However, from a recent study of artificial samples, we suggested (Kane 1977) that Burg spectra should be obtained for a variety of LPEF (33 per cent, 50 per cent, 66 per cent and 90 per cent) and high frequency peacks (*say* above 5th

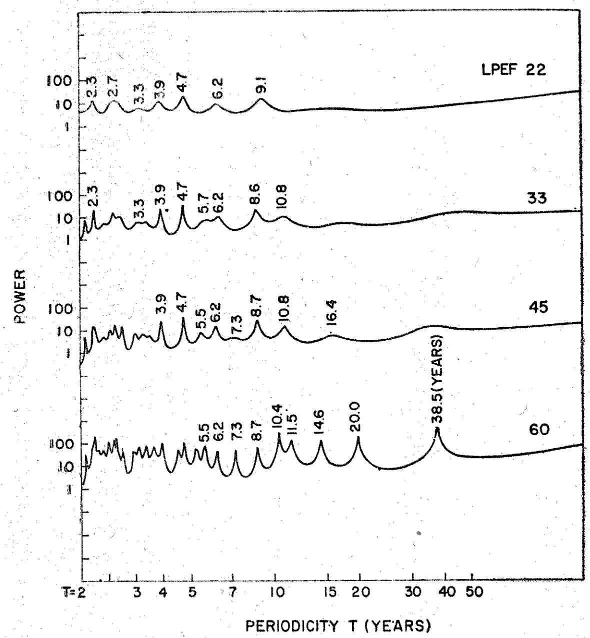

Fig. 1. Burg spectra for the IMD series of dates of the SW monsoon onset over Kerala, for LPEF=22, 33, 45 and 60 representing 33%, 50%, 67% and 90% of the total data length of 66 years (1901-1966)

harmonic) should be sought in low LPEF and lower harmonics in higher and higher LPEF.

Fig. 1 shows the Burg (MEM) spectra for monsoon onset dates from IMD official records (Table 1). While data were available for 1901-1974, we used only the series 1901-1966 leaving the values for 1967-74 for testing predictions as shown later. At low LPEF, *e.g.*, LPEF=22 *i.e.* 33 per cent of the data length 66, a few peaks appear in the high frequency region only. At LPEF=60 (almost 90 per cent of the data length), many more peaks appear in the low frequency region; but high frequency peaks show splitting. Hence, we consider high frequency peaks only in LPEF=22 and 33 and low frequency peaks in LPEF=45 and 60.

Several peaks can be located. However, a major drawback of the MEM is that the height of the power peaks is not necessarily indicative of their prominence. A possible method of judging their significance would be first to locate the peaks T_1, T_2, .. T_n from the Burg spectra and then, assuming that the time series is composed of sine and cosine functions as:

$$f(t) = \sum_{K=1}^{n} \left(a_k \text{ Sin } 2\pi \cdot \frac{t}{T_k} + b_k \text{ Cos } 2\pi \cdot \frac{t}{T_k} \right)$$

$$= \sum_{K=1}^{n} r_k \text{ Sin } \left(2\pi \cdot \frac{t}{T_k} + \phi_k \right)$$

to use standard statistical mothods of least square fit to obtain the best estimates of the amplitudes r_k and their standard error σ_{r_k}.

Burg spectra like those in Fig. 1 were also obtained for the series of Ananthakrishnan *et al.* (1967) and Ramdas *et al.* (1954) (Table 1) and possible peaks (T_k) located and equation (1) used to stimate their amplitudes r_k and standard error σ_{r_k}. The results are shown in Table 2. As can be seen, many of the peaks are significant at 2 σ and 3 σ levels but some others are not, indicating that the latter could have occurred by random causes, due to the limited length of the data series. Peaks having roughly the same periodicity are arranged in the same row. The number of significant peaks is quite large and there is no obvious reason to doubt their bonafides. In the high frequency region (very low periodicities), there seem to be two distinct peaks at T_k= 2.3 and 2.8 years. One of thes, (T_k= 2.3) could be similar to the quasi-biennial peaks at 26 months (2.14 years) reported in rainfall data by Bhargava and Bansal (1969) and Koteswaram and Alvi (1969). Other peaks at T_k= 2.7, 3.5 and 3.9 years seem to be distinct in more than one series with amplitudes of about 3 days. However, the most prominent peak seems to be at T_k= 4.7 years with an amplitude of about 3-5 days at T_k= 6.2 years. In lower frequencies (higher periodicities), there are peaks at about T_k=7, 8, 9, 10, 14, 20 and 40 years with amplitudes of about 2-3 days. There is no prominent 11 year peak. A very large number of peaks in a sample of small data length generally indicates randomness; but we have a suspicion that at least half a dozen peaks are physically genuine. Their origin needs further exploration.

3. Prediction

Do these findings have any predictive value? Mathematically, if a time series is subjected to spectrum analysis and the series recomposed from the spectral components, the larger the number of components used, the better is the fit. However, physical series have a random component involved and hence, when a mathematical fit is obtained as by using equation (1), the fit will be good if a large number of T_k is used. Fig. 2 illustrates the results. In Fig. 2(a), the full lines refer to the onset dates given by Ananthakrishnan *et al.* (1967). The crosses represent the expected values by using the 11 peaks (Table 2) which were significant at a 2σ level. Data used are for 1901-60 only and the expected and observed values match within about $\pm$ 3 days. For 1961-67, the observed values (big dots are within about 5 days of the expected values (cross) except for 1962 when the dot is at May 14 and the corresponding cross at June 11, a discrepancy of 28 days. Fig. 2(b) shows analysis for the same data but using only the 6 peaks which were significant at a 3σ level (*see* Table 2). The quality of matching is about the same as in Fig. 3(a). It seems, therefore,

TABLE 1

Dates of onset of the SW monsoon over Kerala, M=May, J=June, (*a*) IMD, (*b*) Ananthakrishnan *et al.* (1967), (*c*) Ramdas *et al.* (1954).

Year	(*a*)		(*b*)		(*c*)	
1891					27 M	(27)
1892					22 M	(22)
1893					22 M	(22)
1894					1 J	(32)
1895					8 J	(39)
1896					30 M	(30)
1897					30 M	(30)
1898					2 J	(33)
1899					23 M	(23)
1900					6 J	(37)
1901	7 J	(38)	5 J	(36)	1 J	(32)
1902	6 J	(37)	4 J	(35)	31 M	(31)
1903	12 J	(43)	5 J	(36)	8 J	(39)
1904	7 J	(38)	2 J	(33)	29 M	(29)
1905	10 J	(41)	7 J	(38)	6 J	(37)
1906	13 J	(44)	14 J	(45)	3 J	(34)
1907	8 J	(39)	1 J	(32)	31 M	(31)
1908	11 J	(42)	7 J	(38)	8 J	(39)
1909	2 J	(33)	2 J	(33)	1 J	(32)
1910	2 J	(33)	4 J	(35)	28 M	(28)
1911	6 J	(37)	25 M	(25)	1 J	(32)
1912	8 J	(39)	5 J	(36)	4 J	(35)
1913	2 J	(33)	25 M	(25)	24 M	(24)
1914	4 J	(35)	29 M	(29)	28 M	(28)
1915	15 J	(46)	15 J	(46)	3 J	(34)
1916	2 J	(33)	22 M	(22)	26 M	(26)
1917	31 M	(31)	29 M	(29)	26 M	(26)
1918	11 M	(11)	11 M	(11)	7 M	(7)
1919	3 J	(34)	29 M	(29)	16 M	(16)
1920	3 J	(34)	4 J	(35)	27 M	(27)
1921	2 J	(33)	1 J	(32)	1 J	(32)
1922	31 M	(31)	1 J	(32)	25 M	(25)
1923	11 J	(42)	5 J	(36)	4 J	(35)
1924	2 J	(33)	1 J	(32)	31 M	(31)
1925	27 M	(27)	17 M	(17)	27 M	(27)
1926	6 J	(37)	6 J	(37)	28 M	(28)
1927	27 M	(27)	19 M	(19)	23 M	(23)
1928	3 J	(34)	1 J	(32)	31 M	(31)
1929	29 M	(29)	30 M	(30)	29 M	(29)
1930	8 J	(39)	3 J	(34)	21 M	(21)
1931	4 J	(35)	29 M	(29)	23 M	(23)
1932	2 J	(33)	15 M	(15)	14 M	(14)

year	(a)		(b)		(c)	
1933	22 M	(22)	18 M	(18)	22 M	(22)
1934	8 J	(39)	7 J	(38)	6 J	(37)
1935	12 J	(43)	6 J	(37)	10 J	(41)
1936	19 M	(19)	21 M	(21)	20 M	(20)
1937	4 J	(35)	27 M	(27)	3 J	(34)
1938	26 M	(26)	27 M	(27)	1 J	(32)
1939	5 J	(36)	6 J	(37)	6 J	(37)
1940	14 J	(45)	6 J	(37)	7 J	(38)
1941	23 M	(23)	23 M	(23)	23 M	(23)
1942	10 J	(41)	17 M	(17)	4 J	(35)
1943	29 M	(29)	1 J	(32)	12 M	(12)
1944	3 J	(34)	30 M	(30)	29 M	(29)
1945	5 J	(36)	2 J	(33)	1 J	(32)
1946	29 M	(29)	30 M	(30)	29 M	(29)
1947	3 J	(34)	3 J	(34)	31 M	(31)
1948	11 J	(42)	9 J	(40)	25 M	(25)
1949	23 M	(23)	24 M	(24)	23 M	(23)
1950	27 M	(27)	28 M	(28)	26 M	(26)
1951	31 M	(31)	1 J	(32)		
1952	20 M	(20)	21 M	(21)		
1953	7 J	(38)	7 J	(38)		
1954	31 M	(31)	22 M	(22)		
1955	29 M	(29)	11 M	(11)		
1956	21 M	(21)	16 M	(16)		
1957	1 J	(32)	30 M	(30)		
1958	14 J	(45)	14 J	(45)		
1959	31 M	(31)	20 M	(20)		
1960	14 M	(14)	14 M	(14)		
1961	18 M	(18)	19 M	(19)		
1962	17 M	(17)	15 M	(15)		
1963	31 M	(31)	5 J	(36)		
1964	6 J	(37)	7 J	(38)		
1965	26 M	(26)	6 J	(37)		
1966	1 J	(32)	3 J	(34)		
1967	9 J	(40)	8 J	(39)		
1968	9 J	(40)				
1969	17 M	(17)				
1970	26 M	(26)				
1971	27 M	(27)				
1972	18 J	(49)				
1973	4 J	(35)				
1974	26 M	(26)				
1975						

TABLE 2

Amplitudes r_k (in days) with standard errors σ_{rk} for various periodicitie T_k (in years) observed in the Burg MEM spectra for the three time series of monsoon onset dates. Amplitudes significant at 2σ and 3σ levels are indicated by * and ** respectively

(*a*) IMD series		(*b*) Ananthakrishnan *et al.* (1967)		(*c*) Ramdas *et al.* (1954)	
Periodicity (Years)	$r_k \pm \sigma_{rk}$ (Days)	Periodicity (Years)	$r_k \pm \sigma_{rk}$ (Days)	Periodicity (Years)	$r_k \pm \sigma_{rk}$ (Days)
2.3	**3.4±1.0	2.3	**3.5±0.9	2.3	**3.2±0.6
2.7	*2.7±1.0	2.8	**3.3±0.8	2.8	**3.2±0.6
3.3	1.2±1.0	3.5	**2.7±0.9	3.5	**3.1±0.9
3.9	*2.6±1.0	3.9	*2.5±0.9	—	
4.7	**3.9±1.0	4.7	**5.5±0.9	4.8	**2.1±0.6
5.5	1.4±1.0	5.5	*2.1±0.9	5.8	**1.9±0.6
6.2	*2.2±1.1	6.2	**3.4±0.9	6.4	**3.5±0.7
7.3	1.1±1.1	7.3	*1.9±0.9	—	
—	—	—	—	8.0	**2.1±0.7
8.7	*2.8±1.1	8.4	*2.5±0.9	—	
10.4	1.9±1.2	10.8	1.1±0.9	10.8	**2.5±0.6
14.6	0.9±1.1	13.0	1.6±0.9	13.5	**2.9±0.6
20.0	1.2±1.1	20.4	**2.7±0.9	18.6	*1.8±0.6
38.5	*3.1±1.1	41.2	*2.0±0.9	34.7	**3.7±0.7

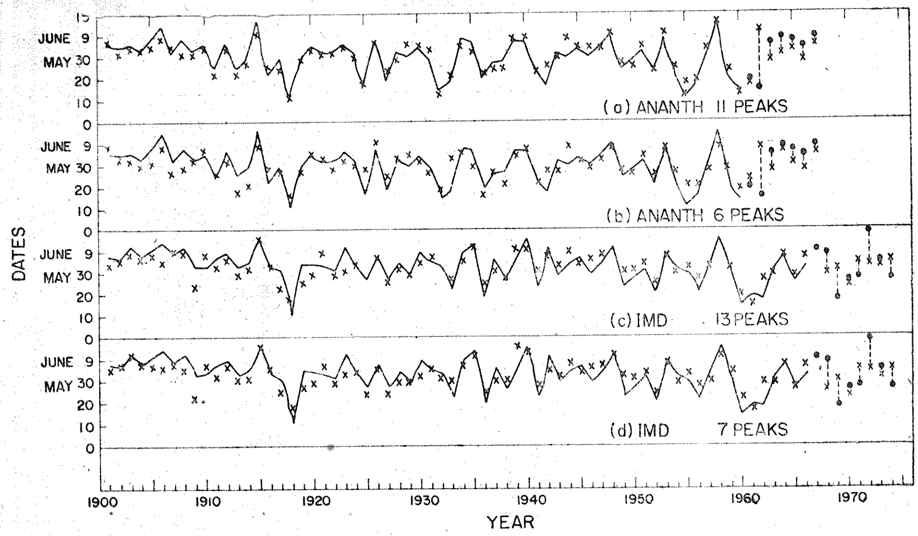

Fig. 2(a-d). Original time series of monsoon onset dates (full lines) and the expected values (crosses) by using peaks from Burg MEM spectra. (*a*) and (*b*) refer to the series of Ananthakrishnan *et al.* (1967) using 11 peaks and 6 peaks respectively for obtaining expected values. (*c*) and (*d*) refer to the IMD series using 13 and 7 peaks respectively. In each case, the analysis was done omitting the last few years, values for which (big dots) are used for comparison with predicted values (crosses)

that predictions with an error of about ± 5 days may be possible.

Figs. 2 (c) and (d) show similar results for the IMD dates, using (c) all the 13 peaks of Table 2 and (d) the 7 peaks which were significant on a 2σ level. Data used were for 1901-66 and the predicted values (crosses) and observed values (big dots) for 1967-74 tally within about ± 10 days. Thus, the prediction seems to have lesser error in case of the dates of Ananthakrishnan *et al.* (1967).

A similar analysis was conducted for the dates of Ramdas *et al.* (1954) using data for 1891-1945 with all the peaks given in Table 2; but the predicted values and the observed values (bracketed) for 1946-50 were 29(38), 31(28), 35(39), 23(29) and 26(13). Thus, deviations as large as 13 were involved, indicating that the predictive value of this series was not very good.

4. Summary and conclusions

A Burg (MEM) spectrum analysis of the dates of onset of the SW monsoon over Kerala as given by (*a*) IMD, (*b*) Ananthakrishnan *et al.* (1967) and (*c*) Ramdas *et al.* (1954) revealed periodicities of about T_k= 2.3, 2.8, 3.5, 3.9, 4.7, 5.5, 6.2, 7.3, 8.5, 10.8, 14, 20 and 40 years with amplitudes of about 2-5 days. When used for predictions, the match was within ± 5 days for the series of Ananthakrishnan *et al.* (1967) and within ± 10 days for the IMD series and the series of Ramdas *et al.* (1954).

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