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Low frequency modes in summer monsoon circulation over India

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सार — हाल के वर्षों में दक्षिणपूर्वी एशिया के ग्रीष्मकालीन मानसून के दौरान 30-60 दिन के दोलन के संरचनात्मक लक्षणों पर अनेक अन्वेषण किए गए हैं, फिर भी अधिकांश अन्वेषण 1979 के मौनेक्स आंकड़ों पर आधारित हैं । वर्तमान अन्वेषणों में भारतीय महाद्वीप के छः वर्षों के व्यापक आंकड़ों का प्रयोग करते हुए लगभग 40 दिन की स्थिति का अध्ययन किया गया है। इस अध्ययन से पता चलता है कि इस बहुलक की आवर्तिता में सार्थक अंतरावर्ष परिवर्तनशीलता है और इसी वर्ष के दौरान इसमें प्रबल स्थानिक निर्भरता है । अन्ततः भारत में ग्रीष्मकालीन मानसून परिसंचरण परिवर्तनों को दर्शाने में इस बहुलक के प्रयोग की सीमाओं का विवेचन किया गया है ।

ABSTRACT. In recent years there has been a large number of investigations on the structural features of 30-60 day oscillations during the summer monsoon of the southeast Asia. However, most of the investigations are based on the 1979 MONEX data. In the present investigation the nature of this near 40-day mode has been studied using a comprehensive data set for six years over the Indian sub-continent. The study reveals that the periodicity of this mode has a significant interannual variability and during the same year it has a strong spatial dependance. Finally the limitations of the use of this mode in foreshadowing the changes of summer monsoon circulations over India have been discussed.

1. Introduction

Madden and Julian (1971) confirmed the existence of a significant low frequency mode oscillation of global nature primarily associated with the zonal component of the wind in the troposphere. Later investigations by Yasunari (1980, 1981) have shown that such a mode propagates northward from equatorial Indian Ocean upto the Tibetan plateau with a quasi-periodic regularity. Alexander *et al.* (1978) have also pointed out the northward shift in the tropospheric circulation anomalies associated with active-break cycles in the summer monsoon over India. Sikka and Gadgil (1980) have studied the existence of 4-6 weekly mode in movement of zone of maximum cloudiness over India. In the summer monsoon season, investigations by Murakami *et al.* (1984) using FGGE level III B data for 1979 have shown that in the monsoon regions spectral peaks with period shorter than 10 days are quite prominent in the lower troposphere. However, their examination, though extensive, in spatial domain (30° S-30° N, 30° E-150° E) was limited to the year 1979. Recent studies of Rama Sastry *et al.* (1986) have shown that though the near 40-day mode was very prominent during 1979 it was rather obscure during 1980, 1981, 1982 and 1983, in the lower tropospheric circulation as well as the rainfall over the Indian subcontinent. In the present investigation Fourier analysis of a much larger data set 1979-84 has been carried out for a number of radiosonde stations over the Indian subcontinent to identify the dominant modes in the summer monsoon circulation at several atmospheric levels (850, 700, 500 and 300 hPa). The study is also aimed at studying the inter-annual variability in this mode.

2. Methodology and data

The radiosonde data of six radiosonde stations, *i.e.*, Trivandrum (TRV), Bombay (BMB), Madras (MDS), Nagpur (NGP), Port Blair (PBL) and Calcutta (CAL) have been used to represent the monsoonal flow. Daily zonal and meridional components of the wind recorded at these stations in m/s have been subjected to harmonic analysis. In order to smooth out the daily and other short period fluctuation 3/5 days moving average of these comoponents were worked out and utilised for the purpose.

3. Discussions

3.1. *Results of harmonic analysis*

Table 1 gives the amplitude and the period of all major harmonics down to a period of 10 days. Figures in bracket below each of these harmonics indicates the percentage of the total variance explained by the harmonics. The analysis was carried out for four levels 850, 700, 500 and 300 hPa for 00 GMT data for six years 1979-1984. Figs. 1(a) & 1(b) show the harmonics of zonal components of 850 hPa and 300 hPa for 1979-1983. Figs. 1(c) and 1(d) show the harmonics of meridional components at 850 hPa and 300 hPa for the same years.

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TABLE 1

Period (days) and amplitude (m/s) of the major harmonics in the zonal wind component of the wind at isobaric surfaces at the selected stations in India in different years (1979-1984). The figure in brackets below each of the harmonics gives the percentage of the total variance explained by the harmonics

1979

850 hPa

Bombay	120 5.4 (37.9)	60 3.8 (18.9)	24 2.5 (8.4)	17.1 1.2 (1.9)
Calcutta	40 2.8 (22.0)	24 2.1 (12.6)	15 1.9 (9.6)	120 0.7 (1.3)
Madras	120 6.9 (45.0)	60 3.9 (14.4)	24 2.5 (5.8)	15 1.6 (2.3)
Nagpur	120 5.1 (34.7)	30 3.1 (12.6)	24 2.4 (7.8)	13.3 1.9 (4.7)
Port Blair	120 5.8 (35.8)	40 3.7 (14.5)	24 3.2 (10.8)	15 1.9 (4.0)
Trivandrum	120 4.8 (36.1)	40 4.1 (27.1)	20 1.8 (5.3)	15 1.5 (3.7)

700 hPa

Bombay	120 5.2 (38.8)	60 3.1 (13.7)	20 2.2 (7.2)	17 1.3 (2.3)
Calcutta	40 4.1 (27.9)	24 2.9 (13.5)	10 1.0 (6.3)	120 0.5 (0.5)
Madras	120 6.3 (35.2)	40 4.8 (19.9)	24 3.7 (12.0)	15 1.4 (1.8)
Nagpur	120 3.3 (22.1)	13.3 2.7 (14.4)	24 2.5 (12.3)	30 2.3 (10.4)
Port Blair	120 4.9 (28.1)	60. 4.0 (18.9)	24 2.9 (9.8)	12 1.6 (2.9)
Trivandrum	120 6.8 (39.4)	40 6.0 (30.5)	15.0 2.0 (3.4)	24 1.8 (2.7)

500 hPa

Bombay	40 3.0 (29.1)	24 2.5 (20.5)	120 1.5 (7.1)	13.3 1.4 (6.2)
Calcutta	30 2.6 (17.0)	120 2.6 (16.8)	24 2.5 (15.4)	15 1.9 (8.8)
Madras	120 6.1 (44.6)	40 4.0 (19.3)	20 2.9 (10.0)	17.1 1.2 (1.7)
Nagpur	30 2.5 (20.4)	20 2.2 (16.5)	13.3 2.2 (15.7)	120 0.7 (1.6)
Port Blair	40 4.3 (30.2)	120 3.4 (19.0)	24 2.0 (6.6)	12 1.7 (4.7)
Trivandrum	120 3.3 (23.9)	60 2.8 (17.3)	15 1.4 (4.3)	20 1.0 (2.4)

300 hPa

Bombay	120 4.3 (47.2)	60 2.2 (12.9)	13.3 1.6 (6.4)	24 0.2 (0.1)
Calcutta	120 6.6 (68.4)	30 2.5 (9.6)	17.1 1.3 (2.8)	20 1.1 (2.0)
Madras	40 2.5 (21.8)	120 2.4 (20.4)	20 1.5 (7.6)	10 1.0 (3.3)
Nagpur	120 5.6 (59.1)	30 2.3 (9.7)	24 1.4 (3.8)	13.3 1.2 (2.9)
Port Blair	120 1.7 (12.4)	40 1.6 (10.7)	12 1.4 (8.1)	24 0.7 (2.4)
Trivandrum	60 1.8 (18.2)	12 1.3 (10.3)	120 1.1 (7.4)	20 0.9 (5.1)

1980

850 hPa

Bombay	120 4.7 (45.2)	60 2.5 (12.6)	24 2.0 (8.3)	15 1.7 (6.1)
Calcutta	40 1.8 (15.6)	13.3 1.8 (15.2)	20 1.3 (8.3)	120 1.0 (4.7)
Madras	60 4.6 (42.0)	120 3.5 (25.4)	24 1.6 (5.4)	15 1.6 (5.0)
Nagpur	120 3.6 (33.6)	30 2.5 (16.1)	13.3 1.9 (9.1)	24 1.6 (6.8)
Port Blair	60 4.2 (46.5)	120 2.4 (15.0)	13.3 1.5 (6.0)	24 1.1 (3.5)
Trivandrum	120 3.4 (31.1)	24 2.4 (15.8)	60 2.0 (10.7)	15 1.8 (8.7)

700 hPa

Bombay	120 5.0 (40.9)	60 3.3 (17.6)	15 2.1 (7.1)	20 1.8 (5.4)
Calcutta	40 1.8 (18.1)	13.3 1.4 (12.1)	24 1.2 (7.7)	120 0.9 (5.1)
Madras	60 3.5 (32.5)	120 3.0 (22.9)	24 1.9 (9.9)	15 1.5 (6.2)
Nagpur	120 2.5 (21.5)	30 2.4 (18.5)	13.3 1.7 (9.9)	24 1.4 (6.1)
Port Blair	60 4.3 (27.8)	13.3 2.6 (10.5)	24 1.6 (3.8)	120 0.7 (0.7)
Trivandrum	60 3.2 (21.4)	120 3.2 (20.6)	24 3.1 (19.6)	17.1 2.1 (8.6)

500 hPa

Bombay	60 2.0 (18.1)	15 1.6 (12.0)	24 1.0 (4.7)	120 0.5 (1.1)
Calcutta	40 2.3 (27.4)	120 2.0 (21.3)	24 1.6 (13.5)	12 0.7 (2.5)
Madras	120 4.1 (24.4)	60 3.4 (22.0)	15 3.2 (15.0)	24 1.9 (5.2)
Nagpur	13.3 2.3 (16.3)	120 1.9 (11.1)	20 1.6 (8.1)	40 1.1 (3.8)
Port Blair	60 3.3 (32.5)	120 2.4 (17.3)	10.9 1.5 (6.2)	20 1.4 (5.7)
Trivandrum	60 2.4 (20.2)	15 2.2 (15.8)	120 1.4 (6.7)	24 0.8 (2.4)

300 hPa

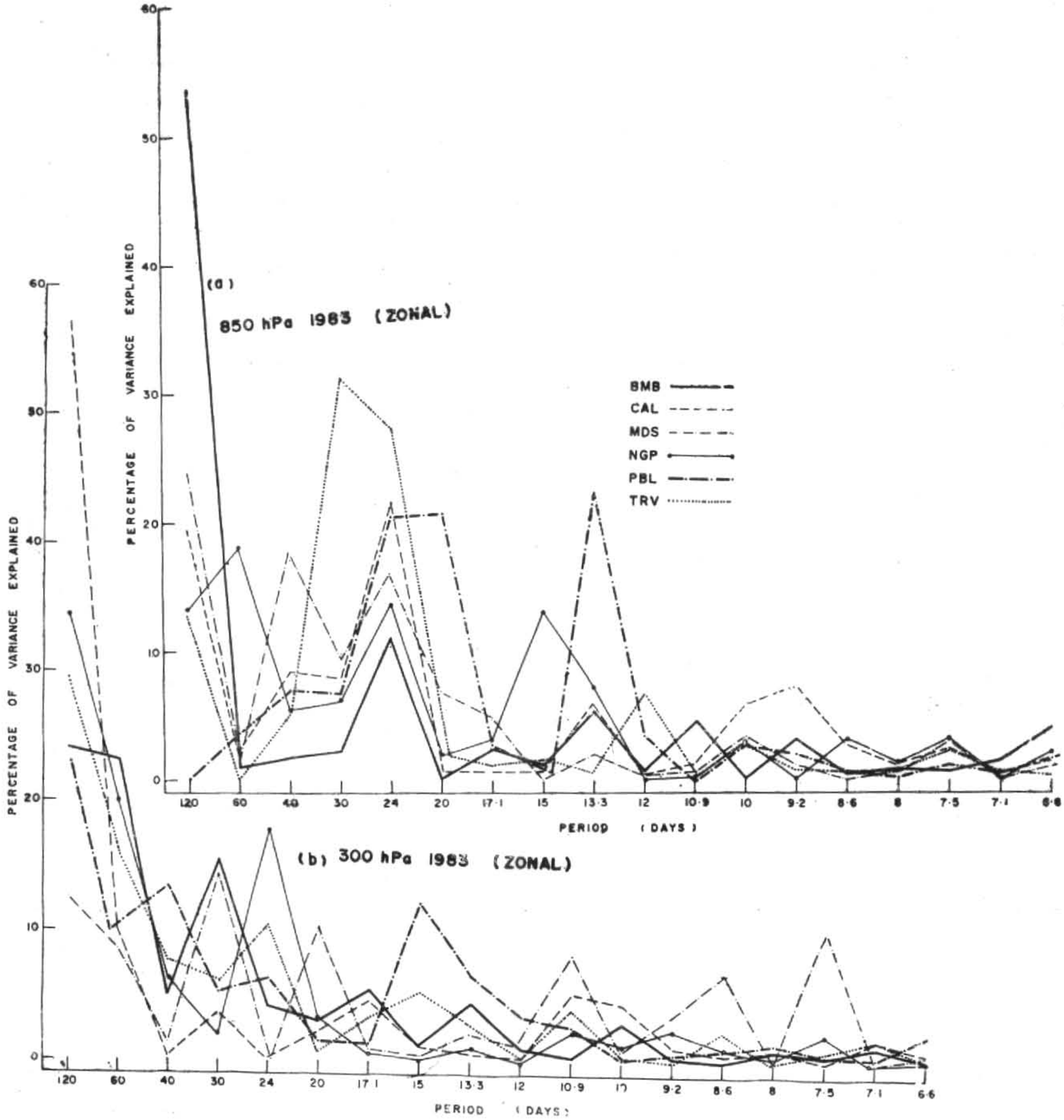
Bombay	120 2.9 (43.0)	13.3 1.5 (11.2)	24 1.4 (10.1)	30 1.0 (4.7)
Calcutta	120 4.7 (62.1)	24 2.0 (11.1)	40 1.5 (6.7)	10 0.9 (2.3)
Madras	120 2.1 (20.7)	17.1 1.6 (11.8)	60 0.9 (3.7)	24 0.8 (2.9)
Nagpur	120 3.6 (56.4)	40 1.5 (9.6)	20 0.8 (2.5)	17.1 0.7 (2.0)
Port Blair	20 1.8 (14.4)	120 1.4 (9.1)	30 1.3 (7.7)	12 1.2 (5.9)
Trivandrum	120 2.9 (24.6)	24 2.1 (12.7)	13.3 1.6 (7.6)	60 1.3 (5.1)

TABLE 1 (*contd*)

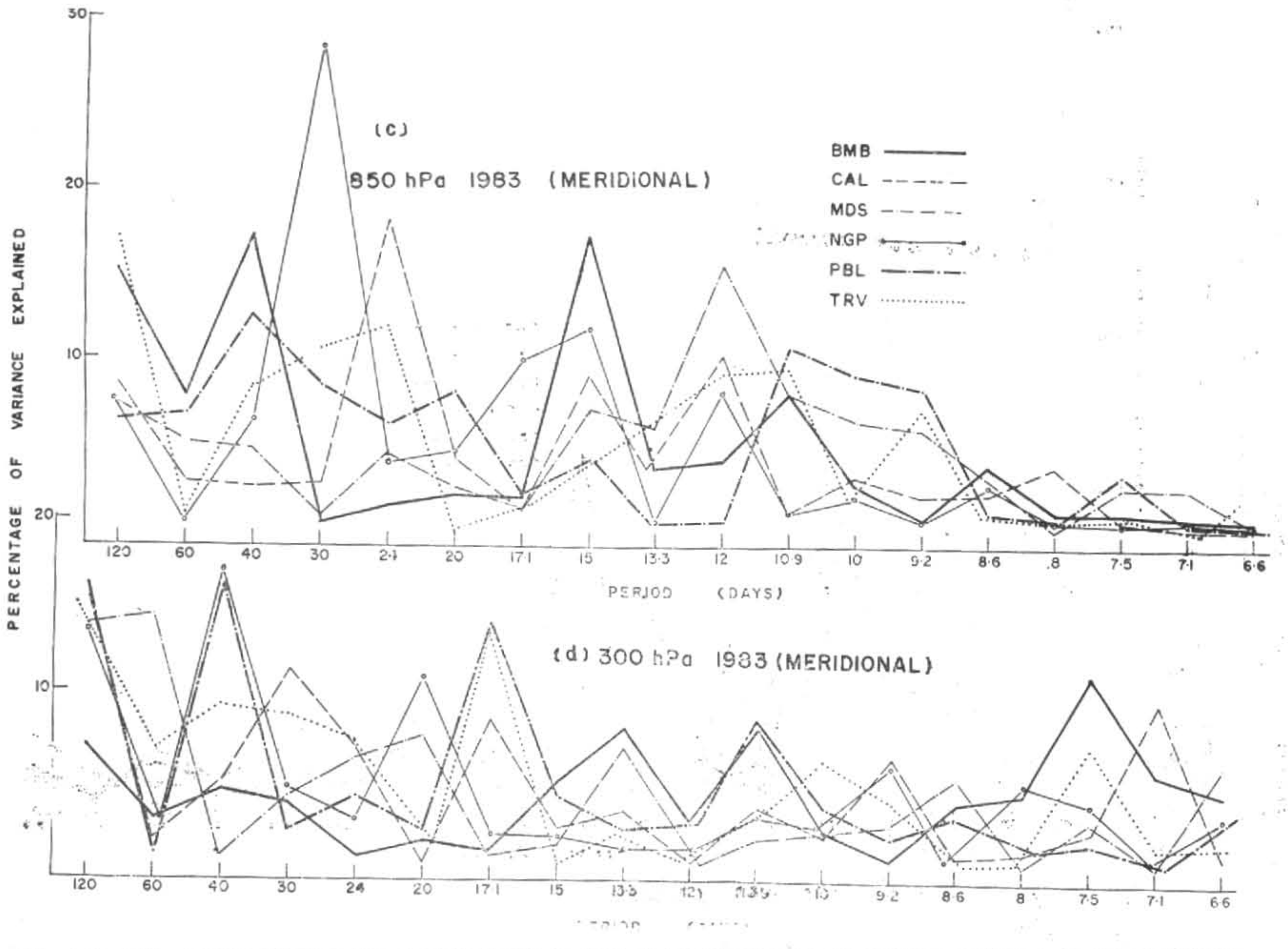
	1981							
	850 hPa				700 hPa			
Bombay	120 5.0 (56.3)	40 2.3 (12.3)	15 1.2 (3.3)	20 1.1 (2.8)	120 6.1 (62.2)	40 3.5 (20.9)	17.1 1.4 (3.3)	24 1.0 (1.7)
Calcutta	24 3.6 (28.3)	60 2.4 (13.1)	15 2.0 (8.6)	120 0.8 (1.5)	24 3.6 (28.6)	40 2.5 (14.0)	15 1.8 (7.4)	120 1.0 (2.1)
Madras	60 4.4 (30.6)	120 3.5 (20.1)	24 2.4 (9.0)	15.0 2.2 (7.8)	120 3.3 (21.6)	60 3.3 (20.5)	15 2.2 (9.1)	24 2.0 (8.1)
Nagpur	120 6.1 (46.0)	60 3.3 (13.1)	24 2.8 (10.0)	10 1.4 (2.4)	120 4.6 (42.4)	40 2.6 (13.7)	15 2.3 (10.3)	20 1.6 (5.3)
Port Blair	60 6.0 (43.2)	24 3.1 (11.9)	15 2.9 (10.3)	120 1.3 (1.9)	60 6.2 (48.6)	24 3.0 (11.1)	15 2.0 (4.9)	120 0.4 (0.4)
Trivandrum	60 2.6 (28.9)	120 1.9 (15.6)	24 1.3 (7.0)	12 1.2 (5.9)	60 5.4 (41.2)	20 2.3 (7.7)	120 1.8 (4.3)	12 1.7 (3.8)
	500 hPa				300 hPa			
Bombay	40 1.7 (16.5)	120 1.7 (15.6)	12 1.3 (9.8)	24 0.8 (3.4)	120 2.5 (30.5)	60 1.9 (17.8)	10 1.7 (13.9)	24 0.3 (0.5)
Calcutta	24 2.6 (15.9)	13.3 2.6 (15.1)	120 2.4 (13.2)	40 1.6 (6.1)	120 5.7 (39.2)	15 3.3 (13.3)	60 2.9 (10.3)	20 2.9 (9.7)
Madras	60 5.0 (28.7)	24 3.2 (11.6)	120 3.0 (10.2)	12 2.6 (7.7)	60 4.0 (37.5)	24 2.0 (9.5)	120 1.6 (6.2)	17.1 1.5 (1.6)
Nagpur	40 2.0 (15.9)	13.3 1.9 (14.9)	20 0.9 (3.4)	120 0.6 (1.6)	120 4.0 (34.5)	15 2.4 (12.8)	20 1.8 (6.7)	40 1.6 (5.7)
Port Blair	60 5.5 (49.3)	24 2.2 (7.7)	120 2.1 (7.4)	15 1.3 (2.8)	13.3 3.0 (11.8)	20 2.7 (9.3)	120 2.5 (8.2)	60 2.3 (6.6)
Trivandrum	60 4.8 (47.7)	12 2.1 (9.6)	24 1.5 (5.0)	120 1.5 (4.6)	60 3.3 (23.6)	120 3.2 (21.8)	24 1.5 (4.6)	12 1.5 (4.6)
	1982							
	850 hPa				700 hPa			
Bombay	120 4.5 (43.6)	60 3.4 (20.3)	24 1.8 (6.8)	15 1.1 (2.7)	120 6.3 (65.0)	60 2.6 (11.1)	24 1.8 (5.1)	15 0.9 (1.2)
Calcutta	120 3.3 (19.5)	24 3.0 (15.9)	40 2.7 (12.8)	10.9 2.1 (7.7)	120 4.0 (27.1)	24 2.5 (11.2)	10.9 2.4 (10.4)	40 1.9 (6.6)
Madras	120 3.6 (31.1)	20 2.2 (11.4)	60 2.2 (11.0)	13.3 2.1 (10.1)	120 5.6 (25.7)	30 4.5 (17.6)	20 3.8 (11.9)	15 3.0 (7.4)
Nagpur	120 4.9 (48.3)	60 3.0 (18.2)	24 1.7 (6.1)	12 1.7 (5.8)	120 4.0 (40.9)	60 1.9 (9.4)	24 1.6 (7.0)	13.3 1.6 (6.7)
Port Blair	120 3.2 (27.7)	60 2.4 (16.0)	13.3 1.8 (8.6)	20 1.0 (3.0)	120 3.0 (20.4)	60 2.9 (19.5)	15 2.0 (9.0)	20 1.0 (2.4)
Trivandrum	30 2.0 (22.6)	120 1.9 (20.0)	13.3 1.3 (8.8)	20 1.1 (6.1)	30 2.3 (16.5)	120 2.1 (13.1)	20 1.8 (10.0)	10.9 1.8 (9.7)
	500 hPa				300 hPa			
Bombay	60 1.6 (15.5)	24 1.3 (10.1)	120 1.2 (9.7)	12 1.1 (7.0)	120 2.1 (19.6)	120 2.3 (15.9)	20 2.3 (15.6)	40 1.5 (6.6)
Calcutta	120 3.6 (29.2)	24 2.4 (13.3)	40 2.0 (9.6)	10.9 2.0 (8.9)	120 4.4 (37.9)	60 2.5 (12.4)	13.3 2.2 (9.5)	24 2.1 (8.4)
Madras	60 3.4 (13.7)	24 3.2 (11.9)	15 2.9 (9.8)	120 1.9 (4.2)	60 1.8 (11.2)	120 1.6 (9.4)	15 1.6 (9.0)	24 1.3 (5.8)
Nagpur	30 2.0 (18.4)	12 1.4 (9.1)	120 1.4 (8.8)	24 1.0 (4.7)	120 3.7 (37.7)	30 2.3 (15.5)	20 1.5 (6.7)	15 1.1 (3.4)
Port Blair	60 2.9 (20.5)	120 2.5 (15.6)	13.3 1.9 (9.2)	20 1.0 (2.7)	40 2.3 (16.2)	120 1.9 (11.3)	10.9 1.7 (9.1)	20 0.9 (2.3)
Trivandrum	13.3 1.9 (13.4)	120 1.8 (13.0)	60 1.5 (8.5)	24 1.1 (4.7)	12 2.6 (20.3)	40 2.1 (13.5)	20 1.7 (8.2)	120 0.7 (1.5)

TABLE 1 *(contd)*

				1983				
	850 hPa				700 hPa			
Bombay	120 4.1 (53.4)	24 1.8 (10.9)	13.3 1.3 (5.3)	30 0.8 (2.3)	120 4.4 (54.0)	13 1.8 (8.5)	24 1.7 (7.6)	30 1.1 (3.2)
Calcutta	24 2.3 (21.5)	120 2.2 (19.5)	40 1.4 (8.5)	13.3 1.2 (5.8)	120 2.5 (21.3)	24 2.4 (19.7)	30 1.6 (9.1)	13.3 1.4 (7.2)
Madras	120 2.9 (24.0)	40 2.5 (17.7)	24 2.4 (16.0)	10 1.1 (3.4)	40 3.4 (31.1)	120 2.8 (20.4)	24 2.3 (14.0)	10 1.1 (2.9)
Nagpur	60 3.1 (18.1)	24 2.7 (13.7)	120 2.7 (13.4)	15 2.6 (13.1)	24 3.4 (29.4)	17 2.3 (13.3)	60 1.9 (9.1)	120 1.5 (5.4)
Port Blair	13.3 2.2 (22.1)	20 2.2 (20.7)	40 1.3 (7.0)	120 0.2 (0.3)	13.3 2.3 (21.4)	24 2.1 (18.3)	40 1.5 (8.5)	120 1.1 (4.5)
Trivandrum	30 2.5 (31.1)	24 2.4 (27.5)	120 1.6 (13.0)	12 1.2 (6.7)	30 3.5 (27.1)	24 3.1 (21.6)	15 1.7 (6.6)	120 1.6 (5.4)
	500 hPa				300 hPa			
Bombay	120 1.5 (11.8)	13.3 1.4 (10.9)	30 0.9 (4.8)	24 0.8 (3.9)	120 2.9 (24.1)	60 2.8 (23.2)	17.1 1.4 (5.4)	24 1.2 (4.3)
Calcutta	120 3.2 (34.5)	24 1.8 (11.0)	10 1.3 (6.3)	30 1.3 (5.4)	120 4.8 (57.3)	60 2.0 (10.1)	10.9 1.5 (5.3)	20 1.0 (2.3)
Madras	120 3.9 (28.2)	13.3 2.1 (8.3)	24 1.7 (5.5)	60 1.7 (5.4)	30 1.8 (14.3)	120 1.7 (12.5)	20 1.5 (10.4)	10.9 1.4 (8.5)
Nagpur	24 3.1 (24.1)	120 2.2 (12.4)	60 1.8 (7.9)	17.1 1.6 (6.3)	120 4.4 (34.6)	60 3.4 (20.0)	24 3.2 (17.8)	10.9 1.1 (2.3)
Port Blair	60 3.3 (27.4)	20 2.8 (20.4)	17.1 1.6 (6.7)	120 1.1 (3.0)	120 2.2 (23.0)	30 1.7 (13.7)	15 1.4 (10.3)	24 1.1 (6.4)
Trivandrum	20 1.7 (12.7)	60 1.7 (12.3)	15 1.4 (8.2)	120 1.3 (7.0)	120 3.5 (29.6)	60 2.6 (16.1)	24 2.1 (10.5)	15 1.5 (5.5)
				1984				
	850 hPa				700 hPa			
Bombay	120 3.7 (38.2)	60 2.4 (16.4)	20 1.8 (9.1)	15 1.4 (5.2)	120 2.9 (21.2)	60 2.5 (15.5)	24 1.7 (6.8)	10 1.4 (4.8)
Calcutta	9.2 2.9 (14.7)	120 2.4 (10.3)	17.1 2.2 (9.0)	60 2.0 (7.0)	17.1 3.9 (14.3)	60 3.1 (8.8)	24 3.0 (8.1)	120 1.2 (1.3)
Madras	120 4.4 (29.2)	60 3.7 (21.1)	15 2.6 (10.0)	20 1.0 (1.5)	60 3.1 (19.4)	120 2.9 (17.6)	15 2.2 (10.0)	20 1.4 (3.9)
Nagpur	60 3.0 (27.3)	120 2.9 (16.0)	15 1.9 (11.4)	24 1.2 (4.2)	15 2.7 (21.2)	120 2.1 (12.9)	30 2.0 (11.6)	24 1.1 (3.6)
Port Blair	60 5.2 (39.0)	17.1 2.7 (10.5)	120 2.1 (6.4)	20 1.6 (3.6)	60 4.5 (31.5)	17.1 2.2 (7.7)	120 2.1 (7.0)	24 2.0 (6.3)
Trivandrum	120 3.4 (30.2)	60 2.7 (18.5)	15 1.8 (8.1)	24 1.8 (8.0)	120 3.2 (17.3)	60 2.8 (13.9)	15 2.7 (12.4)	24 2.5 (11.0)
	500 hPa				300 hPa			
Bombay	24 2.4 (19.5)	40 2.0 (13.1)	120 1.2 (5.1)	15 1.0 (3.5)	120 1.8 (14.0)	15 1.6 (11.4)	40 1.4 (8.9)	24 1.3 (7.7)
Calcutta	120 2.6 (15.6)	15 2.4 (13.5)	24 2.0 (8.9)	30 1.7 (6.7)	120 4.5 (41.0)	24 2.6 (13.3)	30 1.6 (5.0)	15 1.5 (4.6)
Madras	60 3.6 (21.5)	120 3.1 (15.6)	15 2.5 (10.1)	20 1.1 (1.9)	15 3.0 (27.0)	60 2.5 (19.2)	24 1.2 (4.6)	120 1.0 (3.3)
Nagpur	120 1.5 (13.8)	24 1.3 (10.2)	30 1.3 (9.5)	15 1.1 (6.9)	120 2.1 (24.1)	24 1.9 (20.8)	30 1.1 (6.4)	12 0.9 (4.4)
Port Blair	60 4.1 (39.4)	120 2.0 (8.9)	17.1 1.7 (6.4)	24 1.5 (5.1)	24 2.5 (24.3)	120 2.0 (16.5)	17.1 1.7 (11.6)	60 0.8 (2.7)
Trivandrum	24 2.7 (22.7)	60 2.3 (16.8)	120 1.9 (11.2)	10 1.4 (5.8)	60 2.7 (18.7)	17.1 2.5 (16.7)	120 1.7 (7.7)	24 1.1 (3.2)



Figs. 1 (a & b). Graphs showing period of harmonic in days and the percentage of variance explained in the zonal component at : (a) 850 hPa and (b) 300 hPa in 1983



Figs. 1 (c & d). Graphs showing period of harmonic in days and the percentage of variance explained in the meridional component at : (c) 850 hPa and (d) 300 hPa in 1983

It can be seen that the harmonic contributing to the maximum variance of zonal flow in most of the years happens to be the seasonal cycle. In the six years sample examined, the maximum percentage variance explained by the first harmonic in the zonal flow at 850 hPa is 56.3% for Bombay in 1981 and the minimum is 19.5% for Calcutta in 1982. For the zonal flow at 300 hPa maximum variance explained by the first harmonic is 68.4% for Calcutta in 1979 and the minimum is 20.3% for Trivandrum in 1982.

The analysis of the meridional components (Table 2) reveals that the maximum variance explained by 30-60 days for the sample 1979 to 1984 was 33.9% over Port Blair in 1982 and the minimum 2.2% over Trivandrum in 1979.

Both in the zonal and meridional component this mode (30-60 day) can be observed at lower as well as upper tropospheric levels. However, it is more prominent in

TABLE 2

Period(days) and amplitude(m/s) of the major harmonics in the meridional wind component of the wind at isobaric surfaces at the selected stations in India in different years (1979-1984). The figures in bracket below each of the harmonics give the percentage of the total variance explained by the harmonics

1979

	850 hPa				700 hPa			
Bombay	120 2.2 (19.7)	30 2.1 (17.8)	13.3 1.1 (5.2)	20 0.9 (3.5)	40 2.4 (22.0)	20 2.4 (21.1)	13.3 1.9 (13.7)	120 0.6 (1.2)
Calcutta	60 1.6 (9.2)	120 1.5 (8.0)	12 1.5 (8.0)	24 1.2 (2.5)	120 2.9 (21.9)	60 2.1 (17.8)	10 1.0 (4.5)	20 0.8 (2.4)
Madras	20 2.4 (31.1)	12 1.6 (12.5)	40 1.5 (11.1)	120 1.3 (8.7)	30 1.3 (13.9)	12 1.2 (12.9)	120 0.9 (7.4)	24 0.9 (6.4)
Nagpur	20 1.8 (15.0)	30 1.7 (12.8)	150 1.6 (10.9)	120 1.3 (7.4)	13.3 1.5 (16.9)	30 1.4 (15.7)	20 1.2 (10.8)	120 0.8 (4.8)
Port Blair	13.3 1.5 (17.7)	24 1.1 (9.3)	120 0.8 (4.9)	40 0.7 (3.9)	40 1.6 (22.2)	120 1.4 (17.6)	13.3 1.0 (9.9)	24 1.0 (9.8)
Trivandrum	13.3 1.6 (18.5)	120 1.5 (15.4)	24 1.4 (12.8)	60 0.6 (2.2)	8 0.9 (8.0)	20 0.9 (7.9)	10.9 0.9 (7.5)	30 0.8 (6.8)

	500 hPa				300 hPa			
Bombay	40 1.7 (14.1)	24 1.5 (10.7)	13.3 1.3 (9.1)	120 1.2 (7.4)	120 1.4 (18.1)	30 1.4 (17.7)	12 0.9 (7.8)	24 0.5 (2.9)
Calcutta	20 1.3 (11.7)	120 1.3 (11.5)	10.9 1.3 (11.4)	60 1.3 (11.2)	120 1.4 (19.0)	15 1.2 (13.5)	60 0.5 (2.5)	30 0.5 (2.5)
Madras	15 1.0 (18.2)	24 0.9 (17.7)	40 0.6 (5.2)	120 0.4 (2.6)	120 1.0 (14.0)	60 1.0 (13.2)	12 0.9 (10.2)	24 0.7 (7.1)
Nagpur	120 1.6 (18.0)	60 1.1 (8.4)	10.9 0.9 (5.5)	20 0.7 (3.4)	120 1.3 (16.8)	60 1.2 (13.4)	17.1 1.2 (13.3)	24 1.0 (9.4)
Port Blair	7.5 1.2 (12.9)	30 1.2 (12.7)	10.9 1.0 (10.2)	20 1.0 (9.2)	40 1.5 (27.5)	24 0.8 (8.8)	10 0.6 (4.8)	120 0.2 (0.4)
Trivandrum	7.5 1.0 (10.0)	13.3 0.9 (8.5)	40 0.8 (6.6)	120 0.7 (5.8)	40 1.5 (12.6)	120 1.5 (11.5)	20 1.3 (9.2)	13.3 1.3 (9.2)

1980

	850 hPa				700 hPa			
Bombay	120 2.4 (33.5)	60 1.4 (11.0)	20 1.4 (10.9)	13.3 1.3 (10.6)	40 2.6 (24.7)	20 1.6 (9.2)	120 1.3 (5.6)	12.0 1.0 (3.7)
Calcutta	17.1 1.2 (21.4)	24 0.9 (11.2)	60 1.1 (11.0)	12 0.8 (9.8)	24 1.2 (17.4)	12 0.8 (7.4)	30 0.8 (7.3)	120 0.7 (5.8)
Madras	40 1.9 (23.5)	120 1.8 (20.4)	13.3 1.2 (9.1)	20 0.7 (3.4)	60 1.3 (22.5)	20 0.9 (12.4)	10 0.7 (6.4)	120 0.3 (0.9)
Nagpur	30 2.3 (22.0)	120 1.9 (15.3)	12 1.2 (6.3)	24 0.9 (3.0)	120 1.8 (20.5)	30 1.6 (14.8)	20 0.8 (4.0)	10 0.7 (3.2)
Port Blair	13.3 1.2 (19.4)	40 0.9 (11.9)	20 0.5 (3.2)	120 0.6 (2.9)	7 1.4 (16.0)	13.3 1.1 (10.1)	20 1.0 (8.6)	40 0.8 (5.4)
Trivandrum	40 2.1 (17.6)	120 1.5 (9.5)	15 1.4 (8.0)	24 1.1 (5.0)	20 2.1 (27.2)	40 1.5 (14.4)	15 1.1 (8.0)	120 0.1 (0.1)

	500 hPa				300 hPa			
Bombay	17.1 1.6 (11.9)	40 1.4 (8.6)	120 1.3 (7.3)	20 0.7 (2.5)	120 1.6 (31.3)	40 0.9 (8.8)	24 0.8 (7.4)	12 6.0 (3.9)
Calcutta	24 1.0 (13.1)	60 0.9 (10.8)	120 0.8 (8.8)	10.9 0.8 (8.0)	60 1.6 (34.5)	24 1.0 (12.5)	12 0.7 (6.6)	120 0.3 (1.6)
Madras	40 1.5 (17.6)	13.3 1.5 (14.2)	20 1.0 (7.2)	120 0.6 (2.3)	10 1.2 (15.1)	60 0.9 (8.4)	24 0.8 (7.1)	120 0.3 (0.7)
Nagpur	7 1.4 (17.3)	10.9 1.0 (9.4)	40 0.9 (6.6)	24 0.8 (5.9)	60 1.5 (29.7)	120 0.7 (6.5)	10 0.6 (4.9)	20 0.5 (4.1)
Port Blair	10 2.2 (11.6)	60 2.0 (10.1)	120 2.0 (9.3)	20 1.1 (2.8)	30 1.3 (14.6)	15 1.1 (10.2)	24 0.7 (4.1)	120 0.5 (2.5)
Trivandrum	40 1.6 (18.9)	15 1.4 (13.6)	20 1.1 (9.5)	120 0.7 (3.5)	60 1.5 (14.9)	13.3 1.5 (14.3)	20 1.1 (8.4)	120 0.5 (1.6)

TABLE 2 (*contd*)

1981

	850 hPa				700 hPa			
Bombay	120 3.1 (34.5)	40 2.1 (6.6)	24 1.7 (10.0)	12 1.4 (7.2)	120 2.5 (24.5)	60 2.0 (15.9)	24 1.4 (7.8)	15 1.4 (7.3)
Calcutta	20 1.8 (12.1)	40 1.7 (11.3)	10.9 1.5 (8.2)	120 1.0 (3.6)	40 2.5 (19.5)	120 1.7 (9.5)	24 1.6 (7.8)	10.9 1.3 (5.2)
Madras	120 1.9 (19.8)	60 1.7 (16.2)	13.3 1.2 (7.9)	24 1.1 (7.0)	120 1.3 (18.0)	60 1.2 (13.8)	24 1.1 (11.6)	10 0.9 (7.3)
Nagpur	60 3.7 (35.5)	24 1.6 (6.2)	17.1 1.4 (4.8)	120 1.0 (2.5)	60 3.1 (25.3)	20 2.3 (14.3)	10.9 1.5 (5.7)	120 1.4 (5.3)
Port Blair	24 1.2 (14.7)	60 1.2 (13.9)	120 0.8 (6.5)	12 0.7 (4.6)	30 1.3 (16.7)	15 0.9 (8.6)	20 0.6 (3.5)	120 0.7 (0.7)
Trivandrum	120 2.7 (38.5)	12 1.3 (8.5)	40 1.1 (6.1)	20 0.8 (3.4)	120 1.8 (22.0)	30 1.4 (13.7)	20 1.0 (7.5)	12 1.0 (6.9)
	500 hPa				**300 hPa**			
Bombay	15 1.6 (15.7)	60 1.6 (14.7)	24 0.8 (3.6)	120 0.8 (3.3)	120 1.4 (18.3)	10 1.4 (16.3)	60 1.0 (9.3)	20 0.4 (1.3)
Calcutta	24 1.7 (18.1)	10.9 1.0 (6.1)	60 1.0 (6.0)	120 0.9 (5.9)	60 2.1 (28.1)	15 1.5 (13.7)	20 1.0 (5.6)	120 0.3 (0.7)
Madras	60 1.5 (23.5)	13.3 1.2 (15.1)	20 0.7 (4.9)	120 0.5 (2.4)	60 1.7 (21.4)	120 1.3 (12.5)	12 1.0 (7.0)	24 0.6 (2.5)
Nagpur	60 2.7 (26.9)	10.9 1.3 (6.6)	120 1.1 (4.2)	20 0.4 (0.5)	12 1.1 (15.5)	120 0.8 (9.0)	60 0.8 (7.5)	24 0.6 (4.1)
Port Blair	60 1.0 (9.2)	24 1.0 (8.2)	12 1.0 (8.2)	120 0.8 (5.6)	30 1.7 (30.6)	20 0.9 (8.7)	13.3 0.9 (8.6)	120 0.6 (2.9)
Trivandrum	12 1.3 (18.9)	30 1.3 (18.5)	120 1.0 (11.3)	20 0.3 (1.0)	60 2.0 (20.5)	120 1.6 (13.4)	10.9 1.1 (6.2)	24 0.9 (4.5)

1982

	850 hPa				700 hPa			
Bombay	120 4.3 (53.9)	60 1.7 (8.7)	20 1.4 (6.0)	17.1 1.1 (3.7)	60 2.5 (18.7)	15 2.4 (17.3)	120 1.8 (10.1)	20 1.5 (7.3)
Calcutta	40 2.3 (13.0)	10.9 2.2 (11.4)	20 1.9 (8.5)	120 0.6 (0.9)	120 2.8 (20.0)	17.1 1.9 (9.2)	30 1.7 (7.0)	20 1.7 (7.0)
Madras	60 1.3 (13.7)	13.3 1.2 (11.2)	24 1.1 (9.4)	120 0.5 (1.6)	17.1 1.9 (7.9)	20 1.8 (7.5)	40 1.3 (3.5)	120 0.5 (0.6)
Nagpur	24 2.0 (18.3)	60 2.0 (17.8)	120 11.4 (8.6)	10 1.1 (5.9)	120 2.1 (26.1)	20 1.3 (9.9)	40 1.2 (9.1)	10.9 0.9 (5.2)
Port Blair	60 1.7 (24.0)	120 1.4 (14.9)	15 1.2 (12.2)	24 1.1 (10.2)	24 1.4 (17.6)	60 1.1 (10.8)	120 1.0 (8.5)	15 0.9 (7.5)
Trivandrum	24 1.9 (19.7)	120 1.4 (10.5)	40 1.3 (10.3)	15 0.9 (4.8)	24 1.5 (20.8)	13.3 1.3 (14.7)	60 0.7 (4.7)	120 0.4 (1.6)
	500 hPa				**300 hPa**			
Bombay	24 1.6 (17.7)	40 1.3 (11.4)	15 1.0 (7.0)	120 0.3 (0.8)	120 1.8 (29.0)	15 1.1 (9.7)	24 0.9 (7.3)	40 0.6 (2.9)
Calcutta	40 1.7 (14.3)	120 1.4 (9.2)	10.9 1.4 (9.0)	24 1.1 (6.1)	24 2.0 (22.6)	40 1.1 (6.6)	10 1.0 (6.0)	120 0.8 (3.5)
Madras	13.3 1.2 (14.0)	40 1.1 (10.7)	20 0.7 (4.5)	120 0.5 (2.6)	13.3 1.2 (19.6)	60 1.0 (13.9)	20 0.6 (4.6)	120 0.4 (1.6)
Nagpur	10.9 1.4 (21.5)	120 1.4 (20.9)	60 0.7 (4.8)	24 0.4 (1.8)	17.1 1.1 (13.8)	60 0.9 (9.8)	24 0.7 (5.0)	120 0.3 (0.9)
Port Blair	60 1.2 (14.8)	120 0.9 (9.2)	13.3 0.9 (7.5)	24 0.6 (3.4)	40 2.3 (35.9)	120 0.9 (5.8)	17.1 0.8 (4.4)	24 0.4 (1.1)
Trivandrum	40 1.3 (20.8)	15 1.0 (11.4)	120 0.9 (9.3)	24 0.4 (2.2)	60 2.2 (24.6)	20 1.3 (8.4)	13.3 1.0 (5.3)	120 0.9 (4.3)

TABLE 2 *(contd)*

1983

	850 hPa				700 hPa			
Bombay	15 2.2 (17.3)	40 2.1 (17.2)	120 2.0 (15.3)	20 0.7 (1.9)	15 2.3 (20.9)	40 2.0 (16.1)	120 2.0 (15.9)	20 1.3 (6.9)
Calcutta	24 1.1 (18.0)	12 0.9 (10.2)	120 0.8 (8.4)	60 0.5 (2.9)	60 2.2 (21.9)	120 2.0 (18.8)	20 1.3 (7.9)	15 1.1 (5.7)
Madras	12 1.4 (15.8)	120 1.0 (7.3)	60 0.8 (5.2)	24 0.8 (4.5)	60 0.8 (12.4)	15 0.7 (11.1)	20 0.5 (4.7)	120 0.2 (0.7)
Nagpur	30 2.8 (28.4)	15 1.8 (12.0)	120 1.4 (7.6)	20 1.1 (4.8)	12 2.3 (22.0)	40 1.8 (13.1)	20 0.8 (2.8)	120 0.5 (0.9)
Port Blair	40 1.3 (12.6)	10.9 1.2 (10.8)	20 1.1 (8.1)	120 1.0 (6.6)	30 1.2 (14.7)	20 1.1 (11.9)	10.9 1.0 (9.4)	120 0.2 (0.4)
Trivandrum	120 1.8 (17.2)	24 1.5 (12.1)	30 1.4 (10.7)	10.9 1.3 (9.7)	30 1.6 (16.6)	12 1.4 (13.4)	120 1.3 (10.8)	24 0.9 (5.4)

	500 hPa				300 hPa			
Bombay	15 2.4 (16.8)	20 2.3 (16.2)	120 1.7 (8.5)	40 1.4 (5.8)	10.9 1.4 (8.1)	120 1.3 (6.9)	40 1.0 (4.3)	20 0.6 (1.4)
Calcutta	120 1.4 (17.8)	10 1.1 (10.5)	60 1.0 (8.8)	20 0.8 (6.1)	120 1.1 (15.5)	30 0.9 (11.3)	17.1 0.8 (8.5)	24 0.7 (6.8)
Madras	13.3 2.0 (8.6)	30 1.7 (6.2)	120 1.2 (3.0)	24 0.8 (1.5)	60 0.8 (14.4)	120 0.8 (13.9)	13.3 0.5 (6.9)	24 0.5 (6.3)
Nagpur	30 1.5 (13.2)	12 1.2 (9.6)	20 1.1 (7.1)	120 0.5 (1.3)	40 1.3 (17.1)	120 1.1 (13.7)	20 1.0 (11.0)	10.9 0.5 (3.0)
Port Blair	20 2.2 (32.0)	40 1.3 (11.5)	10.9 0.9 (5.3)	120 0.1 (0.1)	60 1.5 (16.2)	120 1.5 (16.0)	17.1 1.4 (14.2)	24 0.7 (3.9)
Trivandrum	40 1.8 (18.5)	24 1.3 (10.7)	17.1 1.3 (10.3)	120 0.4 (0.8)	120 1.6 (15.0)	17.1 1.5 (13.7)	40 1.2 (9.3)	24 1.1 (6.8)

1984

	850 hPa				700 hPa			
Bombay	60 2.2 (28.7)	15 1.4 (11.6)	20 0.9 (4.5)	120 0.8 (3.4)	60 2.2 (25.2)	24 1.7 (14.4)	17.1 1.3 (8.6)	120 1.0 (5.1)
Calcutta	24 3.4 (29.8)	30 2.4 (15.4)	120 1.2 (4.0)	17.1 1.0 (2.6)	17.1 2.6 (13.6)	20 1.8 (6.5)	40 1.3 (3.4)	120 1.3 (3.3)
Madras	60 1.6 (20.4)	24 1.2 (12.1)	10.9 1.0 (7.9)	120 0.8 (4.6)	10 1.4 (21.9)	60 1.0 (11.3)	20 0.6 (4.4)	120. 0.3 (1.2)
Nagpur	60 2.0 (16.3)	17.1 1.6 (10.5)	24 1.4 (8.1)	120 1.2 (5.4)	60 1.4 (14.1)	15 1.1 (8.9)	24 0.8 (4.2)	120 0.7 (3.1)
Port Blair	120 2.2 (25.8)	40 1.4 (9.5)	17.1 1.3 (8.3)	24 1.0 (5.4)	20 1.1 (9.1)	120 1.0 (8.3)	40 0.9 (6.5)	10 0.7 (4.1)
Trivandrum	120 2.4 (35.3)	12 1.1 (7.9)	24 1.1 (7.2)	30 1.0 (6.2)	20 1.2 (16.7)	40 0.8 (7.5)	13.3 0.8 (7.2)	120 0.7 (6.0)

	500 hPa				300 hPa			
Bombay	120 1.5 (11.5)	40 1.4 (9.5)	15 1.3 (9.1)	24 1.0 (5.5)	120 1.1 (16.3)	20 0.8 (8.2)	30 0.7 (6.6)	10.9 0.7 (6.6)
Calcutta	24 1.2 (7.8)	30 1.0 (5.5)	10.9 1.0 (5.4)	120 0.7 (2.7)	30 1.6 (16.6)	10.9 1.0 (6.1)	120 0.9 (5.1)	24 0.8 (4.4)
Madras	40 1.2 (15.0)	10 1.1 (12.7)	24 0.6 (4.5)	120 0.5 (2.5)	17.1 0.9 (8.6)	120 0.8 (6.4)	40 0.8 (5.5)	24 0.7 (4.8)
Nagpur	60 1.4 (20.7)	17.1 0.9 (8.4)	120 0.9 (7.6)	24 0.6 (3.7)	60 1.0 (18.7)	24 0.5 (4.8)	10.9 0.5 (4.6)	120 0.5 (4.4)
Port Blair	20 1.1 (9.9)	30 1.1 (9.8)	120 1.0 (7.4)	10.9 0.9 (5.9)	120 1.2 (10.7)	15 1.1 (9.5)	60 0.8 (5.4)	20 0.8 (4.8)
Trivandrum	12 1.0 (12.2)	60 1.0 (11.8)	120 0.5 (3.1)	24 0.2 (0.5)	120 2.0 (24.4)	60 1.1 (7.9)	17.1 0.9 (5.0)	24 0.4 (1.1)

TABLE 3

Phase angles of zonal and meridional 2nd, 3rd & 4th harmonics of 1979 and 1983 for 850 and 300 hPa levels

Station	Harmonic No.	1979				1983			
		Zonal		Meridional		Zonal		Meridional	
		850	300	850	300	850	300	850	300
Bombay	2nd	15	15	27	50	9	2	25	52
	3rd	30	30	23	34	6	38	18	6
	4th	8	8	16	19	7	3	24	19
Calcutta	2nd	36	2	59	36	19	1	42	7
	3rd	3	21	19	29	12	18	8	30
	4th	12	15	16	4	25	0	21	3
Madras	2nd	8	21	16	53	29	6	37	37
	3rd	23	22	19	32	26	31	15	28
	4th	1	1	9	7	15	7	8	26
Nagpur	2nd	27	2	15	55	29	2	43	9
	3rd	29	32	16	11	19	5	9	3
	4th	13	14	17	9	29	8	17	18
Port Blair	2nd	18	42	59	58	14	3	18	16
	3rd	25	23	1	0	38	2	16	1
	4th	2	27	29	15	1	12	25	13
Trivandrum	2nd	6	3	50	60	14	4	30	42
	3rd	12	35	12	40	34	3	20	4
	4th	27	26	6	1	17	13	0	3

the lower levels both in the zonal and the meridional components. Though this mode is observable in the wind field it shows: (*i*) variable period from one year to the other over the same station for example the predominant period in the zonal flow over Calcutta is 40 days in 1979 and 1980 but it is 60 days in 1984, over Madras it is 60 days in 1980 but 40 days in 1983. (*ii*) In the same year the period varies from one station to the other. In 1979 and 1980 the period is 40 days over Calcutta but 60 days over Port Blair and Madras. (*iii*) In the same year and over the same station the period may vary between the lower and upper troposphere for example in 1979, over Calcutta the period is 40 days at 850 hPa and 700 hPa while it is 30 days over 500 hPa and 300 hPa. (*iv*) Even though the 30-60 days mode is most predominant harmonic at some level it rarely account for the variance in excess of 20 to 30%. In some cases it is as low as 10 to 15%.

In addition to this mode the 10-20 day cycle is also noticed in most of the years with practically same contribution to the variance, for example at 850 hPa over Calcutta in 1980, at 700 hPa over Nagpur in 1979 and at 500 hPa over Calcutta in 1984. This is more prominent in the meridional component.

The maximum variance explained in the sample is 31% in 1979 at 850 hPa over Madras and at other stations the mode is conspicuously seen contributing 10-30% to the variance of the intraseasonal changes in the circulation.

3.2. *Propagation characteristics of the waves*

Table 3 shows the phase angle of the zonal and the meridional components respectively at 2 levels (850 and 300 hPa) for the years 1979 and 1983. This has been studied to identify whether there is a regular south to north progressions in the 2nd, 3rd and 4th harmonics (60 to 30 day period) at all levels. The 3-day moving averages were used as discussed earlier. For the 2nd harmonic with a period of 60 days a phase angle of 6° is equivalent to 1 day while for the 3rd and 4th harmonics phase angle of 9° and 12° respectively are equivalent to 1 day.

In 1979, in the zonal flow we see the phase angles gradually increasing for the 2nd harmonic from Trivandrum to Calcutta at 850 hPa. The phase angle over Port Blair lags behind that of Bombay. The 3rd harmonic does not show a similar regular progression since Calcutta (22° N) has the minimum phase angle and Bombay has a lower phase angle as compared to Trivandrum, Madras and Port Blair. The 4th harmonic shows the least phase angle over Madras, while Bombay, Nagpur and Calcutta have a lower phase angle than Trivandrum which is the southernmost station.

This anomaly in the phase propagation could be due to the fact (Table 1) that at 850 hPa in 1979 the 3rd harmonic is prominent over Calcutta, Trivandrum and Port Blair while the 2nd harmonic is prominent over Bombay & Madras and the 4th harmonic is prominent over Nagpur. This is in line with the findings of Rama Sastry *et al.* (1986) that the near forty-day mode has not only inter-annual variablity but also considerable variation within the same season from one latitudinal belt to the other.

In the meridional component at 850 hPa the lowest phase angle for the 2nd harmonic is seen over Madras followed by Bombay, Trivandrum, Port Blair & Nagpur and Calcutta does not show any systematic south to north progression in the wave. In the 3rd harmonic (40-day) the minimum phase angle is over Port Blair followed by Trivandrum, Madras and Nagpur indicating, perhaps, a south to north movement. However, Bombay and Calcutta have a phase later than that of Nagpur.

In 1983, the 850 hPa zonal circulation appears confusing; the lowest phase angle for the 2nd and 3rd harmonic is seen over Bombay. For the 4th harmonic also the lowest phase angle is over Port Blair followed by Bombay, leaving Trivandrum and Madras. The phase angles of Nagpur and Calcutta appear to be consistent. In the meridional component the 2nd harmonic shows minimum phase angle over Port Blair followed by Bombay. Thus, Trivandrum and Madras do not appear consistent with south to north progression; Calcutta and Nagpur have consistent phase angles. For the 4th harmonic minimum phase angle is over Trivandrum followed by Madras, Nagpur, Calcutta and Bombay. However, Port Blair has a very large phase angle.

In the upper troposphere (300 hPa), a similar analysis was done to see the phase propagation. In 1979, the zonal flow does not show any systematic propagation consistently over all the stations.

In 1979, the meridional component for the second harmonic does not show a south-north propagation. Same is also true for the third harmonic. However, the fourth harmonic shows a south to north propagation between Trivandrum, Madras and Bombay. Nagpur and Calcutta do not show this. In 1983 at 300 hPa the zonal flow does not show a consistent increase in the phase angle from Trivandrum to Calcutta in second harmonic. For the third harmonic the phase angle increases from Trivandrum to Bombay through Madras. However, the phase angle over Nagpur and Calcutta are smaller than that over Bombay. In the fourth harmonic the phase angle of Trivandrum lags behind that of other stations. In the meridional component at 300 hPa the second harmonic does not show increase from Trivandrum northwards. In the third and fourth harmonic there is increase in the phase angle between Trivandrum and Bombay but Madras, Nagpur and Calcutta do not appear to be consistent.

4. Results and interpretation

By detailed analysis of the zonal and meridional component of the wind by resolving it into harmonic components the intra-seasonal variation in the circulation has been studied.The main interest of the study as pointed out earlier is to see how large a fraction of the total seasonal variation is caused by the low frequency mode (30-60 days) over a region extending from 75° E (Bombay) to 93° E (Port Blair) from 8° N (Trivandrum) to 23° N (Calcutta). The important conclusions are :

(1) By far the first harmonic or the seasonal cycle contributes to the largest variance explained in most of the years over most of the stations.

(2) The low frequency mode (30-60 days) shows considerable interannual variability over the same station as well as over different stations. For example, the important harmonic at 850 hPa over Calcutta is 40 days during 1979 and 1980 while in 1981, it is 60 days.

(3) In the same year the mode is not equally important at all stations as interpreted on the basis of the percentage of the variance explained by it.

(4) The vertical structure of the waves show that the period explaining the maximum variance often changes with height and the low frequency mode is more prominent in the lower troposphere.

(5) The low frequency mode in general accounts for less than 30% of the variance in a season and does not have a stable period. As a result, it could be of little use for extended or medium range prediction.

(6) The waves also propagate inconsistently northwards and on a few occasions show a southward propagation also. Such a southward propagation in the deep convection has been reported by Murakami (1984) over the summer monsoon region of the northern hemisphere.

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