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Low frequency oscillations in tropospheric winds during contrasting summer monsoon over India

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सार — मानसून की परस्पर विपरीत परिस्थितियों अर्थात सूखा और अच्छे मानसून के दौरान वर्षा की गतिविधि के आधार पर, स्पेक्ट्मी विश्लेषण तकनीक द्वारा भारत के ऊपर क्षोभमंडलीय पवनक्षेत्र में निम्न आवृति के उच्चावचन का अध्ययन किया गया है। इन वर्षों के दौरान उल्लेखनीय स्पेक्ट्मी शीर्षों का पता चला है। निम्न क्षोभमंडल में पवन के अक्षांशीय अपरूपण का भी अध्ययन किया गया और 40 दिनों के आसपास के मोड की आवर्तिता ज्ञात की गई है। मोड की अन्तरवार्षिक परिवर्तिता और मध्य अवधि पूर्वानुमान के लिए एक साधन के रूप में इसकी संभाव्यता की उचित परिप्रेक्ष्य में जाँच की गई है।

ABSTRACT. The low frequency fluctuations in the tropospheric wind field over India has been studied by spectrum analysis technique. during contrasting monsoons. namely. drought and good monsoons based on rainfall activity. Significant spectral peaks during these years have been identified. Zonal wind shear in the lower troposphere have also been examined and the periodicity in the near 40-day mode have been documented. The interannual variability of the mode and its potential as medium range prediction tool has been examined in the proper perspective.

Key words — Low frequency oscillations, Spectrum analysis techniques, Zonal wind shear, Interannual variability.

1. Introduction

Temporal and spatial variation of summer monsoon rains plays a vital role in India's economy. Short. medium and long term forecasting of rainfall activity during summer monsoons are very vital for agricultural and hydrological planning in the country. Any study related to the Indian monsoon variability either interannual or intraseasonal. thus. has significant role in understanding the Indian rainfall activity.

Madden and Julian (1971) observed low frequency oscillations of 40-50 days period in tropical regions. Yasunari (1979) analysed the cloudiness over the eastern hemisphere during the monsoon of 1973. The study revealed two dominant periodicities around 40 and 15 days. He indicated northward movement of cloudiness from equatorial zone to mid-latitudes over Asian monsoon region and southward movement over western and central Pacific. He associated this period with active/break cycle of the summer monsoon. In case of 15 days period. he observed two clockwise rotating waves over India—SE Asia and over western Pacific. He suggested that the former is associated with global scale zonal oscillation particularly in equatorial zone and later as a result of meridional wave interactions. In another study. using long period data of cloudiness. Yasunari (1980) observed a quasi-stationary 30-40 day period over Indian summer monsoon. It was absent in one of the drought years. 40-50 days period was observed by Sikka and Gadgil (1980) in the cloud bands which seemed to move from south to north over India. They attributed this period to the active/break cycle of Indian monsoon activity.

The 40-day period was observed in other meteorological parameters too. Yasunari (1981) noted the same period of 40 to 50 days in geopotential and wind fields, during summer monsoon not only over India but also over neighbouring areas. Ramasastry *et al.* (1986) attempted to use the 40-day mode quasi-stationary period in medium range forecasting of Indian rainfall and found that it does not have a significant skill score because of variability in the period from year-to-year. Singh and Kripalani (1985) analysed pentad rainfall over different grids over India and observed 40-day period which moved from south to north. In another study, Singh and Kripalani (1986) showed a linear relationship between mean sea level height of 700 hPa and rainfall with a period of 40 days over India. Low frequency oscillations in the two time scale of 10-15 and 30-50 days based on rainfall features over India were noticed by De and Vaidya (1987). They examined that the auto-correlation between rainfall series with lags ranging from one to seven weeks over broad areas. The maximum auto-correlation in the low frequency mode (lag four to seven weeks) was found to be around 0.3 for central part of the country. This accounts to a variance of less than 10%. In another study based on long series of data, De *et al.* (1988) observed the 40-day mode in upper wind over the Indian subcontinent. Subsequently, Chowdhury *et al.* (1988) confirmed the low frequency oscillation in monsoon cloudiness and rainfall over India. They observed that 10-20 day oscillations were stronger in good monsoon year. Attempts were also made to relate the low frequency oscillation, mainly 40-day period by Singh and Kripalani (1990) with ENSO activity. The present authors have tried to

detect the low frequency oscillation in upper winds and zonal wind shear during contrasting monsoon activity years over India which has not been done so far. They selected a set of representative rainfall, active or non-active years mainly normal, good and drought years.

2. Data

The basic upper wind data of the monsoon for the years 1979 to 1984 and 1987 are used in the study. Out of these, some selected years, *viz.*, 1979, 1982, 1987, 1981 and 1983 were analysed. The former 3 years were deficient and the later 2 were normal/excessive rainfall years (Appa Rao and Srivastava 1991). The upper wind data for six radiosonde stations of Thiruvananthapuram (TRV), Bombay (BMB), Madras (MDS), Calcutta (CAL), Nagpur (NGP) and Port Blair (PBL) over south India were used in the analysis. Four standard isobaric levels, *viz.*, 850, 700, 500 and 300 hPa were selected representing the lower, middle and upper tropospheric levels of the atmosphere. Besides the above data, the wind shear of 850 hPa between pairs of stations representing the west coast, central and east coast of peninsula were also studied. The station pairs are Madras-Nagpur, Port Blair-Calcutta, Thiruvananthapuram-Bombay. The analysis of wind shear data has been attempted as these are useful predictors in the medium range time scale (De 1990).

3. Method of analysis

The winds were resolved into zonal and meridional components. The wind data as well as zonal shear were subjected to spectrum analysis as given by Blackman and Tukey (1958) and WMO Tech. Note No. 79 (1978). The data of winds analysed refer to the following :

850, 700, 500 and 300 hPa wind data for Bombay, Calcutta, Madras, Nagpur, Port Blair and Thiruvananthapuram for 1979-1984 and 1987 were analysed.

850 hPa zonal shears between Madras-Nagpur, Port Blair-Calcutta, Thiruvananthapuram-Bombay, which are useful predictors in medium range scale (Ramasastry *et al.* 1986), have been analysed for larger data set, *i.e.*, 1972, 1973, 1979-1984 and 1987.

The maximum lag considered for the analysis was 60, which yielded 61 spectral estimates, covering the period ranging from 2 to 120 days. The spectral peaks which are of 95% significance level were identified (WMO 1978) and are given in the Tables 1 and 2.

Diagrams indicating the spectral values at all the stations for zonal, meridional wind components and wind shears are prepared. For brevity, important spectral features in period ranges, namely, 10-20 and 30-60 days are given in the tables. The results of spectral analysis for Thiruvananthapuram, a representative station, are shown in Fig. 1. However, the salient features obtained for all the stations ar discussed in the paper.

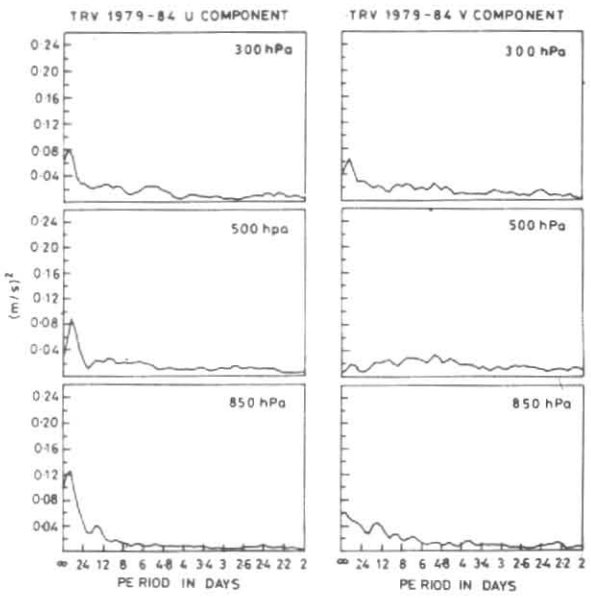

Fig. 1. Spectral values at three levels (850, 500 and 300 hPa). The years 1979-84 monsoon for Thiruvananthapuram

4. Results and discussion

The salient features obtained from the analysis of the wind data at different levels for the six stations during 1979-84 and 1987 monsoon seasons are tabulated. Significant peaks at 95% level as mentioned are marked by asterisks. Attempts are made only to discuss the periods in the range of 10-20 and 30-60 days at these stations as given in Table 2. Other periods which do not fall in the above two ranges are omitted in the table. In Table 1, important periods in the zonal wind shear for the above two ranges in three sections of stations are given, besides results of 1987 are also shown.

Peaks varied much from station to station and with height. However, on close observation of tables some common points are noticed :

(*i*) The wave activity is generally more in the meridional component than in the zonal component.

(*ii*) The wave activity is more over west coast compared to other areas. Thiruvananthapuram-Bombay, which lie along the west coast suggest significant peaks of about 60 days period throughout the troposphere in the zonal wind. Meridional wind suggests wave around 20 days in all

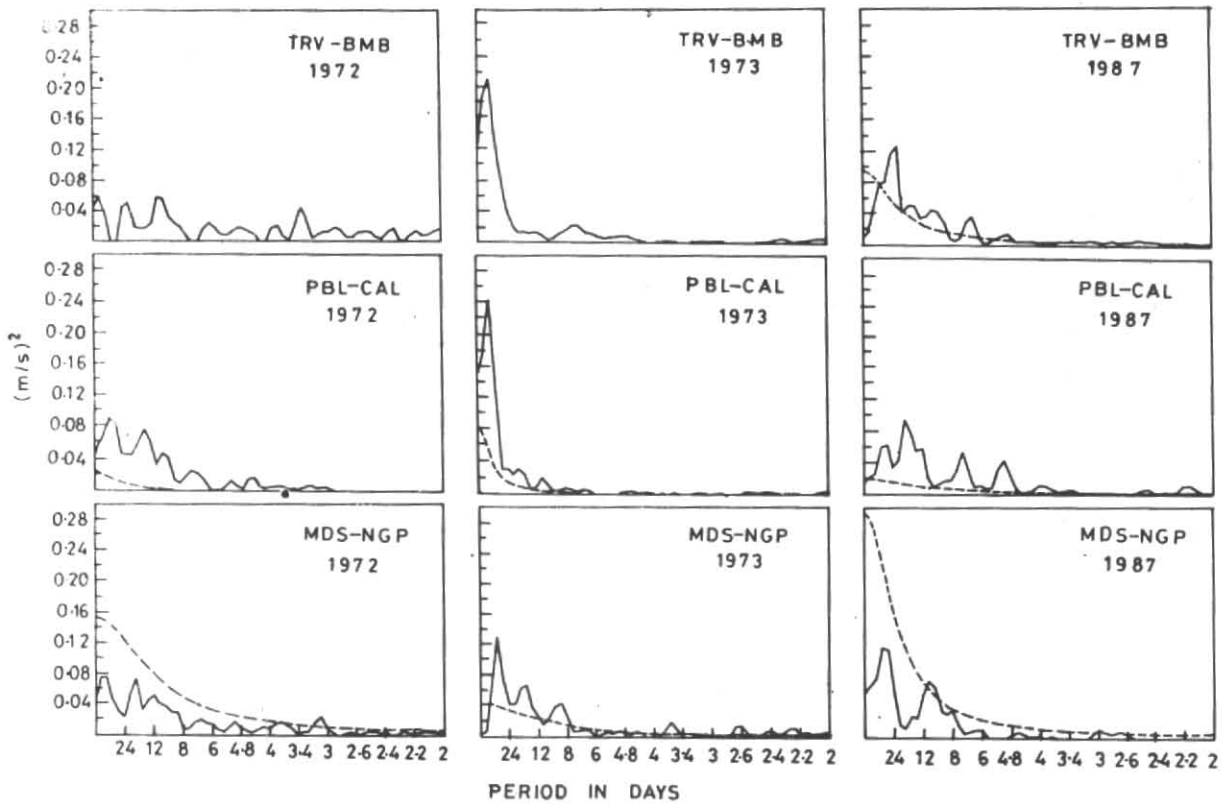

Fig. 2. Spectral values at 850 hPa level of zonal shear anomaly for the years 1972, 1973 and 1987 for the station pairs MDS-NGP, PBL-CAL and TRV-BMB. Dotted lines indicate significant values (95% level)

TABLE 1

Periodicity (in days) for spectral peaks in wind shear ($u_1 - u_3$) at 850 hPa between the pairs of station during monsoon of 1972 and 1973, 1979-1984 and 1987

Station	1972	1973	1979	1980	1981	1982	1983	1984	1987
MDS-NGP	60.0	*40.0	30.0	—	*60.0	—	*30.0	—	40.0
	17.1	*15.0	12.0	*13.3	*17.1	*12.0	*20.0	13.3	15.0
	12.0				12.0		*13.3		10.9
PBL-CAL	*40.0	*60.0	*40.0	*60.0	*60.0	*30.0	—	*60.0	*30.0
	*13.3	*17.1	*12.0	*15.0	*12.0	*10.0	—	*17.1	*17.1
	*10.0								*12.0
TRV-BMB	—	*60.0	—	*40.0	*60.0	*60.0	*60.0	*60.0	—
	*20.0	—	*20.0	*15.0	*20.0	*13.3	*20.0	*15.0	*10.9
	*10.9						*15.0	*10.0	

* — Significant values at 95% level

the years. The activity of this wave is generally less during 1979, a predominantly drought year. In the years of normal or above normal seasonal monsoon rainfall other waves of different periodicities are seen. It is also of interest to note that 1979 indicates less meridional wind activity. In case of Bombay, 40 days period appears to be dominant in the zonal component during 1979.

(*iii*) Calcutta and Madras represent east coast of India where waves with period of 30-40 days are generally seen at lower levels and sometimes 60 days at higher levels. This is particularly significant at Calcutta as compared to Madras.

(*iv*) Port Blair suggests the period of 40-60 days dominant in the lower levels.

TABLE 2

Periodicity (in days) for observed spectral peaks during 1979-1984 and 1987 monsoon seasons at different stations over India in zonal (u) and meridional (v) winds at different levels

Station	Level (hPa)	1979		1980		1981		1982		1983		1984		1987	
		u	v	u	v	u	v	u	v	u	v	u	v	u	v
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Thiruvananthapuram	850	*60.0 *20.0	— *13.3	— *15.0 *12.0	*40.0 —	*60.0 *10.9	— *17.1 *12.0	*30.0 *13.3	*60.0 —	*30.0 *12.0	*30.0 *12.0	*30.0 *15.0	*13.3	— *13.3	— *12.0
	700	*60.0	— *20.0 *10.9	—	*40.0 —	*60.0 *20.0	*30.0 —	*30.0 *13.3	*60.0 *13.3	*30.0 —	*30.0 *15.0 *10.9	*30.0 *15.0	*40.0 *20.0	*60.0 *17.1	— *10.9
	500	*60.0 *13.0	— —	*60.0 *15.0	*40.0 *20.0 *15.0	*60.0 *12.0	*30.0 *12.0	— *13.0	*40.0 *15.0 *10.9	*60.0 *10.0	*40.0 *17.1 *15.0	— *15.0	*60.0 *12.0	*60.0 *12.0	— *10.9
	300	*60.0 *20.0 *10.0	— *20.0 *13.3	— *15.0	*60.0 *20.0 *13.3	*60.0 *30.0	*60.0 — —	*60.0 *12.0	*60.0 *20.0	*40.0 — —	*60.0 *30.0 *17.1 *10.0	*60.0 *17.1 *10.9	— —	*40.0 — —	— — —
Bombay	850	40.0 —	*30.0 *15.0 *10.0	*20.0 *13.3	*20.0	60.0 15.0	*60.0 *20.0 *12.0	— *15.0	— *17.1 *12.0	— 10.9	*40.0 *15.0 *10.9	— *17.1	*60.0 *15.0	*60.0 *10.9	*40.0 *17.1
	700	*40.0 —	*40.0 *20.0 *13.3	*15.0	*40.0 *12.0	*60.0 *15.0	*60.0 *17.1	— —	*60.0 *15.0	— *10.9	*40.0 *15.0 *10.0	*40.0 —	*60.0 *10.9	*60.0 *10.0	— *15.0
	500	*40.0 *13.3	*40.0 *20.0 *13.3	*60.0 *15.0	*40.0 *17.1 *12.0	*40.0 *17.1 *12.0	*60.0 *15.0 *10.0	60.0 12.0	— *12.0	*60.0 *13.3 *10.0	*40.0 *15.0	— —	*40.0 *15.0 *10.0	*60.0 *13.3	— *20.0
	300	*60.0 *15.0	*30.0 —	— *13.3	— *10.0	*60.0 *10.0	— —	— 20.0 10.0	— *15.0 *10.0	*30.0 —	— *12.0	*60.0 *15.0 *10.0	— —	— *13.3	*40.0 *15.0
Madras	850	— —	*60.0 *13.3	*60.0 *20.0	*40.0 *15.0	*60.0 —	*60.0 *13.3	30.0 13.3	*60.0 *13.0	*60.0 —	— *15.0 *12.0	— *15.0	*60.0 *12.0	*60.0 —	*30.0 —
	700	*60.0 —	*30.0 *12.0	*60.0 *13.3	*60.0 *20.0	*60.0 *15.0	*60.0 *10.0	*30.0 *12.0	— *12.0	*40.0 —	*60.0 *15.0	— *15.0	*60.0 *10.0	*60.0 *12.0	— *10.0
	500	— *17.1 *10.0	— *17.1	*60.0 *15.0	*40.0 *13.3	*60.0 *12.0	*60.0 *13.3	*60.0 *10.9	*40.0 *12.0	— *12.0	— *20.0 *12.0	*60.0 *12.0 *10.9	*40.0 *10.9	— —	— *10.0
	300	*40.0 *20.0 *10.0	*10.0 *12.0	— *17.1 *12.0	*60.0 *13.3 *10.0	*60.0 *12.0	*60.0 *12.0	*60.0 *15.0	*60.0 *13.3	*60.0 *20.0 *10.9	*60.0 —	*60.0 *15.0	*60.0 *17.1	— *13.3	— *10.0
Calcutta	850	40.0 15.0	*60.0 *15.0	*40.0 *13.3 10.0	*60.0 *17.1 *10.9	*60.0 *15.0	*40.0 *20.0	60.0 *13.3	*40.0 *10.9	*30.0 *13.3	— *12.0	— —	— —	30.0 15.0	*40.0 *17.1
	700	*40.0 *13.3	— *15.0	*40.0 *13.3	*30.0 *12.0	— *15.0	*40.0 *10.9	— *13.3	*60.0 *10.9 *12.0	*30.0 *13.3	*30.0 —	*60.0 *20.0	— *20.0 *12.0	*40.0 *15.0	— *15.0

TABLE 2 *(Contd.)*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Calcutta	500	—	—	*40.0	*40.0	*60.0	*60.0	*60.0	*60.0	*30.0	*30.0		—	*60.0	*60.0
		*30.0	*20.0	—	*20.0	*13.3	—	*10.9	—	*17.1	—	*15.0	—	*15.0	*15.0
		*15.0													
	300	—	—	—	*60.0	—	*60.0	*60.0	*60.0	*30.0	*30.0	—	*30.0	—	
		*17.1	*15.0	*10.0	*20.0	*15.0	*15.0	*13.3	*13.3	*10.9	*10.0	—	—	*15.0	*20.0
			*12.0		*13.3										*12.0
Port Blair	850	60.0	*30.0	*60.0	*40.0	*60.0	*60.0	*40.0	*40.0	*40.0	*30.0	*60.0	—	*60.0	*60.0
		—	*13.3	*10.0	*15.0	*15.0	—	*10.0	*15.0	*20.0	*10.0	*17.1	*17.1	*13.3	*10.0
					*10.0			*15.0		*13.3		*12.0	*10.0	*10.0	
	700	*60.0	*40.0	*60.0	—	*60.0	*40.0	*30.0	—	*40.0	*30.0	*60.0	*40.0	*60.0	*30.0
		*20.0	*12.0	*13.3	*13.3	*12.2	—	*10.0	—	*17.1	*10.9	*17.1	*20.0	*17.1	*10.0
								*15.0		*12.0		*12.0			
	500	*40.0	*30.0	*60.0	*60.0	*60.0	*60.0	30.0	*60.0	*60.0	*40.0	—	*30.0	*60.0	—
		*20.0	*10.9	*20.0	*17.1	—	—	*13.1	*13.1	*20.0	*20.0	*17.1	*20.0	—	*10.0
					10.9				*10.0			12.0			
	300	—	*40.0	*30.0	*30.0	*40.0	*30.0	*40.0	*40.0	*40.0	*40.0	*60.0	—	*30.0	*60.0
		*10.9	—	*12.0	*15.0	*13.3	*13.3	—	*17.1	*15.0	*17.1	*15.0	—	*10.0	*15.0
							*10.0				*10.9	*10.9			*10.0
Nagpur	850	—	60.0	*30.0	*30.0	*40.0	*60.0	*40.0	*60.0	*40.0	*30.0	*60.0	*30.0	*40.0	*60.0
			30.0	—	—	—	—	—	—	—	—	—	—	—	—
		12.0	*15.0	*13.3	*13.3			*12.0	*10.0	*15.0	*17.1	*20.0	*17.1		*17.1
				*10.0							*12.0	*15.0	*12.0		*12.0
	700	—	*40.0	*30.0	—	*60.0	*60.0	*40.0	—	—	*40.0	*60.0	*60.0	*60.0	*60.0
					—					—		*30.0			*13.3
		*13.3	*20.0	*13.3	—	*15.0	*20.0	*12.0	*20.0	—	*12.0	*15.0	*15.0		
		12.0	*13.3	*10.0			*13.3					*10.9			
							*10.9								
	500	—	—	—	—	*40.0	*60.0	*30.0	—	—	*30.0	—	—	*40.0	*40.0
		*20.0	*17.1	*13.3	*10.9	*20.0	*12.0	*17.1	*10.9	*12.0	*12.0	*15.0	*17.1	—	*20.0
		*13.3		*10.9		*13.3		*12.0							*13.3
								*10.0							
	300	—	*60.0	—	*60.0	—	—	*30.0	*60.0	—	*40.0	—	*60.0	—	*60.0
													*30.0		
		*12.0	*17.1	*10.9	*20.0	*15.0	*12.0	*13.3	*13.3	—	*20.0	*12.0	*17.1	*20.0	
			*10.0										*10.9		

* — Significant peaks at 95% level

(v) Nagpur suggests lower level of activity. Significant peaks of 60 days are seen in the drought years only over this station. The upper tropospheric levels appear to be less active compared to the middle ones.

The analysis of wind shear for the years 1972, 1973, 1979-84 and 1987 are shown in Table 1. Waves with period in the range of 10 to 20 days are more compared to 30 to 60 days and particularly so in drought years. These are shown in Fig. 2.

Fig. 1 shows the results at three levels, namely, 850, 500 and 300 hPa for the whole data covering 1979 to 1984 monsoons. These diagrams indicate significant peaks of 13.3, 15.0 and 60 days throughout the troposphere. This suggests the existence and prevalence of low frequency oscillations of 15 and 60 days both in meridional and zonal components over Thiruvananthapuram. These periods are statistically significant as viewed against the long series of data. 850 hPa suggests periods in the range of 12-30 days in all the years. They are prominent in good or excessive years when compared to the drought years. Good years are generally associated with higher wave activity compared to drought years. In case of 500 hPa zonal wind component the activity is less compared to the lower levels. However, the meridional wind component at

this level in all the years suggests higher wave activity. 300 hPa suggests higher wave activity both in zonal and meridional wind components with zonal wind component having significant periods of 60 days and 10-20 days.

5. Conclusions

Thus we may summarise that :

(*i*) The near 40-day mode shows considerable interannual variability. this reconfirms the earlier findings of Ramasastry *et al.* (1986) and De *et al.* (1988).

(*ii*) Further. the mode is not very coherent spatially: during the same year the period varies in the vertical plane over the same station. *viz.*. during 1981 the significant period in the zonal wind component over Bombay at 850 hPa is 60 days while at 500 hPa it is 40 days. Likewise during the same year the significant period may be different over different locations (latitude & longitude) at the same vertical level.

(*iii*) Yet another outcome of the analysis points out that even if the mode is present it is not significant at 5% or 10% level of significance at all the levels and over all the stations.

(*iv*) Generally speaking mode appears more prominently along the west coast. *viz*.. Thiruvananthapuram and Bombay.

(*v*) The mode appears to be somewhat more significant during the years of normal or excess seasonal rainfall.

(*vi*) The zonal wind shear along the west coast (Thiruvananthapuram-Bombay) shows absence of significant low frequency modes during major drought years like. 1972, 1979 and 1987.

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