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Trends and quasi-biennial oscillation in the series of cyclonic disturbances over the Indian region

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ABSTRACT. Seasonal and annual frequencies of cyclonic disturbances that occurred over the area extending from Lat. 5°N to 35°N and Long. 50°E to 100°E for the period of 80 years from 1891 to 1970, have been examined by fitting orthogonal polynomials and by power spectrum analysis.

The analyses reveal a significant falling trend in the number of cyclonic disturbances in the SW monsoon season. This fall seems to have begun at the start of the present century. Annual cyclonic disturbances show a falling trend after 1940 upto 1965 and rise afterwards. The long period oscillation of about 40 years is seen in the SW monsoon and annual number of cyclonic disturbances. There is also an evidence of quasi-biennial oscillation in the number of cyclonic disturbances during SW monsoon season.

1. Introduction

A statistical study of cyclonic disturbances (storms/ depressions) in the Bay of Bengal has been made by Rao and Jayaraman (1958). They arrived at the conclusion that there is no trend or periodicity in the series of annual cyclonic disturbances in the Bay of Bengal. The storm atlas (1964) gives frequencies, direction, movement, speed, recurvature etc of cyclonic disturbances. It is reported that there is decrease in the annual number of cyclonic storms since 1930.

The existence of the quasi-biennial oscillation (QBO) in the stratospheric temperature and zonal wind is well established (Reed 1965). In recent years the puzzling phenomenon of the QBO received considerable interest and attempts were made to detect its existence in the tropospheric parameters. Landsberg *et al.* (1963) had found a significant QBO in surface parameters.

In this study seasonal and annual frequency of cyclonic disturbances (storms/depressions), that occurred over the Indian region for the period of 80 years from 1891-1970 is examined by fitting orthogonal polynomials and by power spectrum analysis to see whether some trend or QBO could be detected.

2. Data

Seasonal and annual frequencies of cyclonic disturbances, that occurred over the area extending from Lat. 5°N to 35°N and Long. 50°E to 100°E, for the period of 70 years from 1891 to 1960 were extracted from the atlas of storm tracks (1964) and for 10 more years from 1961 to 1970 from the unpublished storm tracks available at the office of the Deputy Director General of Observatories (Forecasting), Poona.

3. Trend analysis

In order to examine trends or long term variations, orthogonal polynomials of the 5-th degree as developed by Fisher explained by Goulden (1959), were fitted to the time series of seasonal and annual frequencies of cyclonic disturbances. The series were normalised by the transformation $X=\sqrt{Y}+\sqrt{Y+1}$ (Freeman and Tukey 1950) so as to facilitate the analysis of variance to test the significance or otherwise of trend.

The results of the fitting of the fifth degree to the transformed series are given in Tables 1 to 4. The transformed frequency of cyclonic disturbances and fitted curves are shown on the lower diagrams of Figs. 1 to 4. The original series of cyclonic disturbances together with fitted curves are also shown in upper diagrams of respective figures for comparison. Description is given in respect of transformed series curves.

3.1 *Premonsoon (March to May).*

First degree coefficient is the only one which is positive and just significant at the 5 per cent level indicating rising trend. The power spectrum analysis which is explained in subsequent section, does not indicate the trend.

Polynomial curve in Fig. 1 shows a slight rise from 1900 to 1930, and does not show any trend afterwards.

3.2. *Monsoon (June to September)*

First degree coefficient is negative and significant at the 1 per cent level. Negative value of the

TABLE 1

Cyclonic disturbances — March to May
Analysis of variance for individual degrees of fitting

	Coeff.	SS	DF	MS	F	EV
Mean	2·82					
First degree	*·0857	1·81	1	1·81	4·2	5
Second degree	—·0265	·30	1	·30	·7	1
Third degree	—·0170	·19	1	·19	·4	1
Fourth degree	·0204	·38	1	·38	·9	1
Fifth degree	·0018	0·00	1	0·00	0·0	0
Residual		31·40	74	·42		
Total		34·08				8

TABLE 3

Cyclonic disturbances — October to November
Analysis of variance for individual degrees of fitting

	Coeff.	SS	DF	MS	F	EV
Mean	4·25					
First degree	·0320	·25	1	·25	·6	1
Second degree	*—·0603	1·57	1	1·57	4·1	5
Third degree	·0174	·20	1	·20	·5	1
Fourth degree	*·0466	2·01	1	2·01	5·2	6
Fifth degree	—·0183	·43	1	·43	1·1	1
Residual		28·09	74	·38		
Total		32·55				14

*Significant at per 5 cent level

TABLE 2

Cyclonic disturbances — June to September
Analysis of variance for individual degrees of fitting

	Coeff.	SS	DF	MS	F	EV
Mean	6·26					
First degree	**—·2266	12·64	1	12·64	31·4	27
Second degree	—·0258	·29	1	·29	·7	1
Third degree	—·0191	·24	1	·24	·5	1
Fourth degree	·0123	·14	1	·14	·3	0
Fifth degree	**·0522	3·49	1	3·49	8·6	7
Residual		29·78	74	·40		
Total		46·58				36

** Significant at 1 per cent level

TABLE 4

Cyclonic disturbances —Annual
Analysis of variance for individual degrees of fitting

	Coeff.	SS	DF	MS	F	EV
Mean	8·16					
First degree	*—.0915	2·06	1	2·06	5·8	6
Second degree	*—·0664	1·90	1	1·90	5·3	6
Third degree	—·0013	0·00	1	0·00	0·0	0
Fourth degree	·0368	1·25	1	1·25	3·5	4
Fifth degree	·0302	1·17	1	1·17	3·3	4
Residual		26·16	74	·35		
Total		32·54				20

* Significant at 5 per cent level

first degree coefficient indicates a falling trend totalling about 4 cyclonic disturbances over the 80-year period. Linear trend accounts for 27 per cent of the total variability for the series. The series also show a significant fifth degree trend indicating oscillations in the series with a period of about 35 years.

The nature of the changes in the frequency of cyclonic disturbances for monsoon can be seen in polynomial curve in Fig. 2. The curve shows a general falling trend from the start of the present century. The long period oscillation of about 40 years is also perceptible in the curve.

3.3. *Post-monsoon* (*October to November*)

Linear trend is not significant in the series. Second and fourth degree trends are just significant at the 5 per cent level. Polynomial curve in Fig. 3 shows a slight rise from 1900 till about 1925 and falls slowly afterwards.

3.4. *Annual*

First degree coefficient is negative and significant at the 5 per cent level indicating a falling trend, totalling about 2 cyclonic disturbances over the 80-year period. Second degree trend is also significant at the 5 per cent level.

Polynomial curve in Fig. 4 displays practically no change upto 1940 followed by fall from 1940 to about 1965 and then it rises to the end of the series considered. Rao and Jayaraman (1958), on the other hand, reported no trend in their analysis

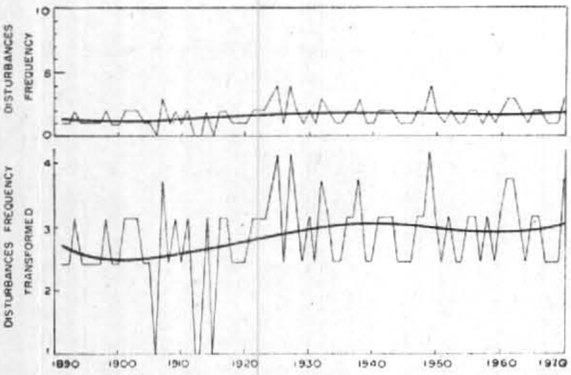

Fig. 1. Pre-monsoon

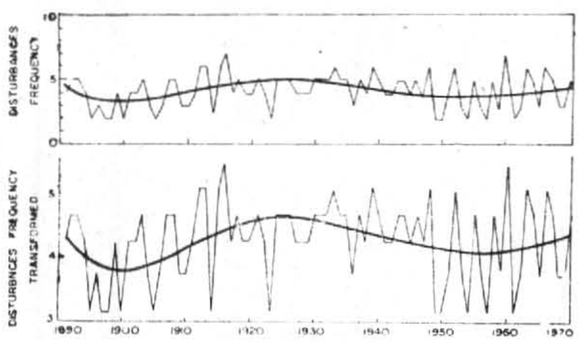

Fig. 3. Post-monsoon

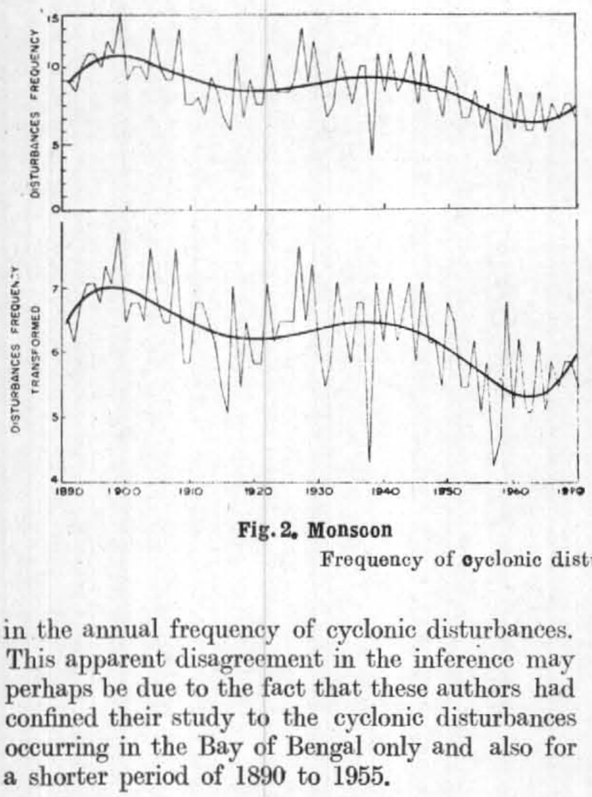

Fig. 2. Monsoon

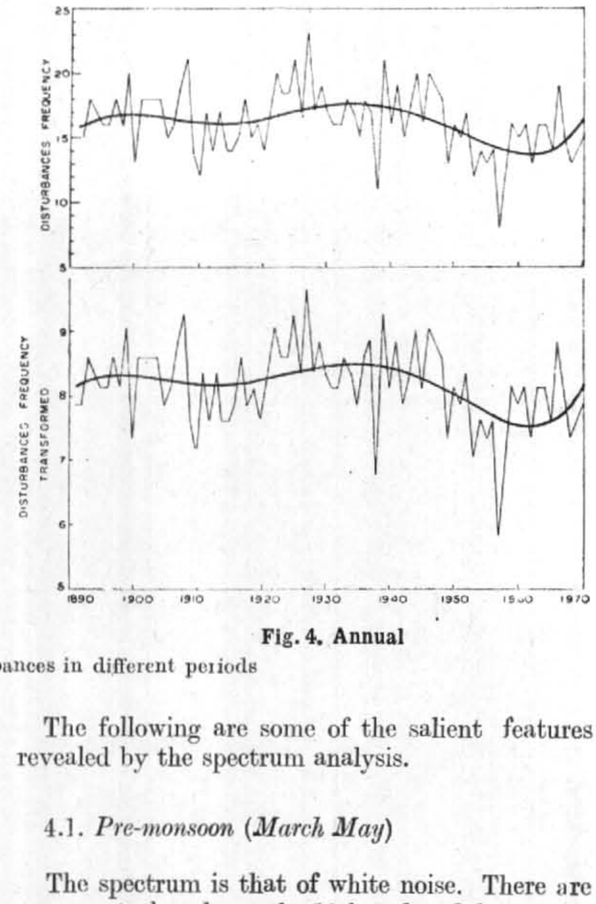

Fig. 4. Annual

Frequency of cyclonic disturbances in different periods

in the annual frequency of cyclonic disturbances. This apparent disagreement in the inference may perhaps be due to the fact that these authors had confined their study to the cyclonic disturbances occurring in the Bay of Bengal only and also for a shorter period of 1890 to 1955.

4. Spectrum analysis

The fluctuations noticed may perhaps be due to any systematic oscillations or due to any aperiodic variation. To ascertain the frequency of such oscillations, the original time series of cyclonic disturbances were subjected to power spectrum analysis. The computational procedure outlined in the WMO Technical Note (1966) on climatic change was adopted for this study. Power spectra of seasonal and annual series of cyclonic disturbances are shown in Fig. 5. These were calculated with a maximum lag of 20 years.

The following are some of the salient features revealed by the spectrum analysis.

4.1. *Pre-monsoon (March May)*

The spectrum is that of white noise. There are two spectral peaks at the 18th and 15th harmonics corresponding to periodicity of 2·2 years and 2·7 years respectively. But none of these spectra peaks is significant even at 90 per cent level. This indicates that the series of pre-monsoon cyclonic disturbances is random.

4.2. *Monsoon (June-September)*

The spectrum is that of red noise and the time series contains persistence of Markov linear type. The spectral peak at 0th harmonic corresponding to wave of infinite period (linear trend) is significant at 95 per cent level. The other spectral

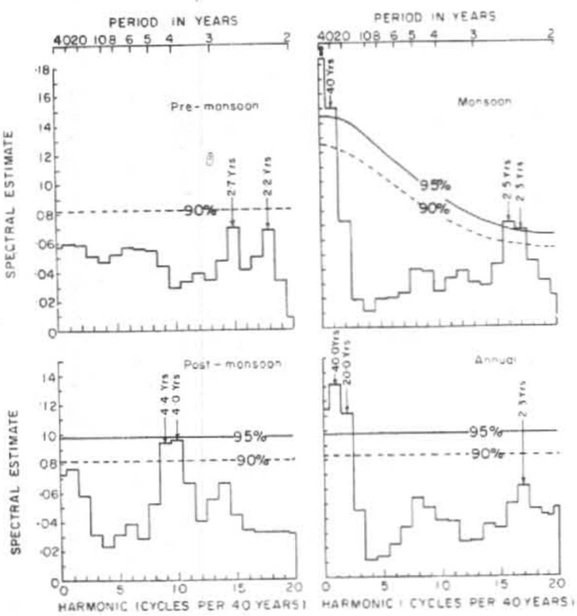

Fig. 5

Power spectra of cyclonic disturbances series over the Indian region

peak at harmonic 1 corresponding to the wave about 40-year period is also significant at 95 per cent level. The spectral peaks at 17th to 16th harmonics corresponding to periodicity of 2·3 to 2·5 years are significant at 95 per cent level, indicating that there is also an evidence of quasi-biennial oscillation in the number of cyclonic disturbances during SW monsoon season. It is of interest to note that Koteswaram and Alvi (1969) and Jagannathan and Bhalme (1970) have found the evidence of this QBO in SW monsoon rainfall and also in some of the characteristic parameters representing the pattern of SW monsoon rainfall over India.

4.3. *Post monsoon (October-November)*

The spectrum is that of white noise. The spectral peaks for 9th and 10th harmonics corresponding to periodicity of 4·0 to 4·4 years are significant only at 90 per cent level. These peaks may perhaps be due to randomness.

4.4. *Annual*

The spectrum is that of white noise for annual series of cyclonic disturbances. The spectral peaks at 0th, 1st and 2nd harmonics are significant at 95 per cent level. The maximum spectral power is in the band centred at 40 years.

In the higher frequency end of the spectrum, the spectral peak at the 17th harmonic corresponding to the periodicity 2·3 years is detectable but the peak does not reach even 90 per cent level of significance.

5. Summary and conclusions

(*i*) These analyses reveal a significant falling trend in the number of cyclonic disturbances for SW monsoon season. This fall seems to have begun at the start of the present century. Annual number of cyclonic disturbances shows a falling trend after 1940 upto 1965 and rises afterwards.

(*ii*) The long period oscillation of about 40 years is also seen in the SW monsoon and annual number of cyclonic disturbances.

(*iii*) The frequency of SW monsoon cyclonic disturbances has a significant quasi-biennial oscillation (QBO) with a period of 2·3 to 2·5 years.

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