

Periodicities in the frequency of Indian monsoonal cyclonic disturbances and storms

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सार — इस शोध पत्र में स्पेक्ट्रल विश्लेषण के विषय में चर्चा करते हुए उत्तरी हिंद महासागर के क्षेत्र में (5° उ., -35° उ., 50° पू. — 100° पू., बंगाल की खाड़ी और अरब सागर दानों को साथ लेते हुए) 1890 से 1999 तक के दौरान बनने वाले मानसून अवदाबों और तूफानों की बारम्बारता के क्रम से (क) चक्रवातीय विक्षोभ के $T \approx 40$ वर्षों की अत्यंत महत्वपूर्ण आवर्तिता और $T = 2-3$ (क्यूबी.ओ.) 3.7, 4.6, 8.8 और 21.8 वर्षों की नाममात्र का महत्वपूर्ण आवर्तिताओं, तथा (ख) चक्रवातीय तूफानों की $T \approx 37$ वर्षों की अत्यंत महत्वपूर्ण आवर्तिता और $T = 2-3$ (क्यूबी.ओ.), 11.4 और 15.4 वर्षों की महत्वपूर्ण आवर्तिताओं का पता चलता है।

ABSTRACT. When subjected to a spectral analysis, the series of the frequency of monsoon depressions and storms formed over the north Indian Ocean area (5° N - 35° N, 50° E - 100° E, Bay of Bengal and the Arabian Sea taken together) for 1890-1999 indicated (a) a highly significant periodicity at $T \approx 40$ years, and barely significant periodicities at $T = 2-3$ (QBO), 3.7, 4.6, 8.8, and 21.8 years for cyclonic disturbances, and (b) a highly significant periodicity at $T \approx 37$ years, and significant periodicities at $T = 2-3$ (QBO), 11.4, and 15.4 years for cyclonic storms.

Key words — Monsoon depressions, Cyclonic storm, North Indian Ocean, Spectral analysis, Periodicities.

1. Introduction

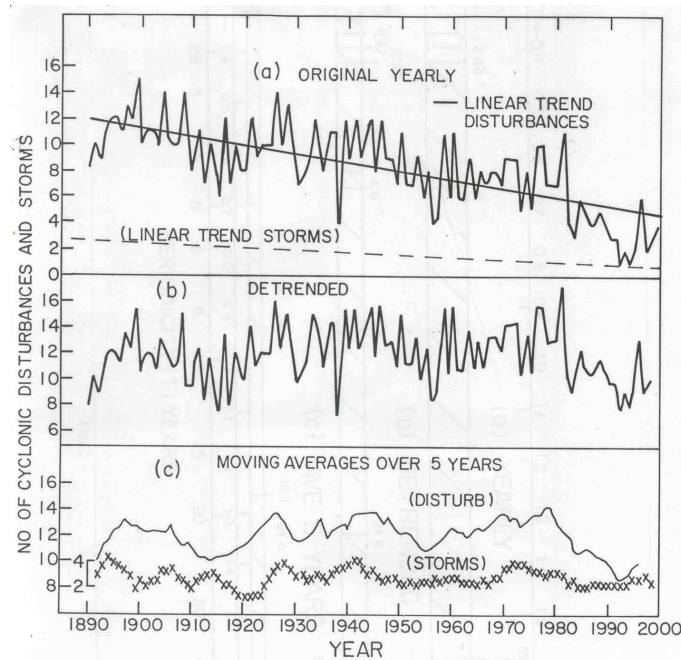
Tropical cyclones and depressions play an important role in the climate of tropics. In India, monsoon depressions forming over the north Indian Ocean, particularly over the Bay of Bengal, are important for the summer rainfalls over the central and northern parts of India. Some climatological studies on the storms and depressions in the Indian seas have been reported (Rai Sircar, 1958), and many of these studies deal with the prediction of the movement of these systems (Sikka and Suryaarayan, 1968; Datta and Gupta, 1975; Neumann and Mandal, 1978). Recently, Singh (2001) examined the frequency of monsoon depressions and cyclonic storms formed over the north Indian Ocean area (5° - 35° N, 50° - 100° , Bay of Bengal and the Arabian Sea taken together) for 1890-1999, and reported significant long term trends, namely, a decrease of frequency of cyclonic disturbances at the rate of -6.6 disturbances per hundred years and a decrease of frequency of cyclonic storms at the rate of -1.9 storms per hundred years, in the monsoon season. In the present communication, the same data are examined to see if there were any significant periodicities during 1890-1999.

2. Data

Singh (2001) obtained data from the IMD atlas (IMD, 1979), its addendums published by IMD in 1996, and further information from the quarterly Journal Mausam and IMD records. For the present analysis, the values were read out from Singh (2001, Fig. 1, page 656).

3. Plots

Fig. 1(a) shows a plot of the number of cyclonic disturbances (one value per year, during the monsoon months June-September) for 1890-1999. The full straight line is the linear downtrend, estimated by Singh (2001) as -6.6 (number of disturbances) per hundred years, significant at a 99% level. (Values for individual years for cyclonic storms are not shown, only the linear downtrend for storms is shown by the dashed straight line). However, there are considerable year-to-year fluctuations. After removing the linear trend, Fig. 1(b) shows the detrended values of cyclonic disturbances. To eliminate short-term fluctuations, moving averages over five consecutive yearly values were calculated. These are plotted in Fig. 1(c), full line for cyclonic disturbances and crosses for



Figs.1 (a-c). Plots for 1890-1999 of the frequencies '(number of monsoonal cyclonic disturbances) (a) yearly values (the full straight line is the linear trend for cyclonic disturbances and the dashed straight line is the linear trend for cyclonic storms), (b) yearly values detrended, (c) moving averages of detrended values over 5 consecutive years

cyclonic storms. Some periodic structures are seen, with peaks not exactly the same for disturbances and storms. To study these quantitatively, a spectral analysis was done.

4. Spectral analysis

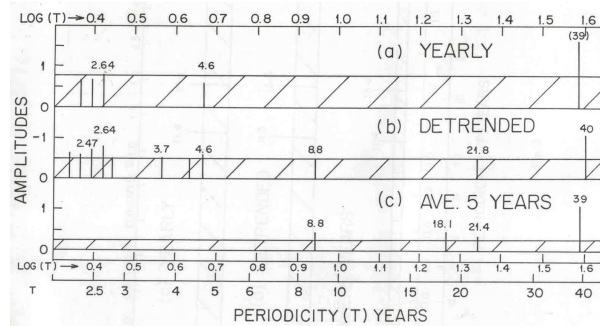
To obtain quantitative estimates of the characteristics of the interannual variability, the series were subjected to spectral analysis. The method used was MEM (Maximum Entropy Method, Burg, 1967; Ulrych and Bishop, 1975), which locates peaks much more accurately than the conventional BT (Blackman and Tukey, 1958) method. However, the amplitude (Power) estimates in MEM are not very reliable (Kane, 1977, 1979; Kane and Trivedi, 1982). Hence, MEM was used only for detecting all the possible peaks T_k ($k = 1$ to n), using LPEF (Length of the Prediction Error Filter) as 50% of the data length. These T_k were then used in the expression :

$$f(t) = A_0 + \sum_{k=1}^n [a_k \sin(2\pi / T_k) + b_k \cos(2\pi / T_k)] + E$$

$$= A_0 + \sum_{k=1}^n r_k \sin(2\pi / T_k + \phi_k) + E$$

where $f(t)$ is the observed series and E the error factor. A Multiple Regression Analysis (MRA, Bevington, 1969) was then carried out to estimate A_0 (a_k , b_k), and their standard errors (by a least-square fit). From these, amplitudes r_k and their standard error σ_k (common for all r_k in this methodology, which assumes white noise) were calculated. Any r_k exceeding 2σ is significant at a 95% (a priori) confidence level.

Fig. 2 shows the spectra (amplitudes *versus* periodicity T) for cyclonic disturbances. To get good resolution, the abscissa scale is $\log(T)$. The hatched portion indicates the 2σ level, and peaks protruding above the hatched area are significant at a 95% level. Fig. 2(a) refers to the yearly values. Some periodicities are seen in the QBO region (Quasi-biennial oscillations, 2-3 year periodicities), but these are of only border-line significance. The periodicity $T = 4.6$ years is not significant. In contrast, a very prominent, highly significant periodicity is seen at $T = (39 \pm 1)$ years. If the linear trend is removed, the spectra of the detrended series are as shown in Fig. 2(b). Here too, a few QBOs are seen; some are significant ($T = 2.64$ years), while $T = 3.7, 4.6, 8.8, 21.8$ years are barely significant. In contrast, $T = (40 \pm 1)$ years stands out prominently. Spectra of the



Figs. 2(a-c). Spectra (amplitudes versus periodicities) of the time series of the number of cyclonic disturbances for (a) yearly values, (b) yearly values detrended, (c) moving averages of detrended values over 5 consecutive years. The hatched portion indicates the 2σ level, and peaks protruding above the hatched area are significant at a 95% level. The abscissa scale is logarithmic, $\log(T)$

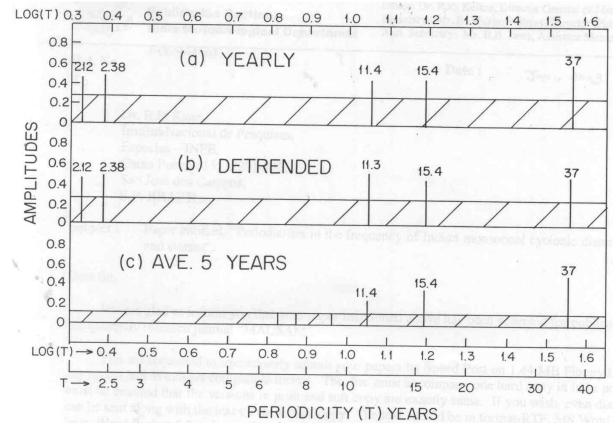
smoothed plot of Fig. 1(c) are shown in Fig. 2(c). As expected, lower periodicities are wiped out, $T = 8.8$, 18.1 , 21.4 , years are barely significant, and $T = (39 \pm 1)$ years stands out prominently.

Fig. 3 shows spectra for cyclonic storms. In the yearly values, some significant QBOs are seen ($T = 2.12$, 2.38 years). There are significant periodicities near $T = 11.4$, 15.4 years, which were not seen in cyclonic disturbances (Fig. 2). There is a strong periodicity at $T = 37$ years, which is roughly the same as the $T = (40 \pm 1)$ years for the disturbances.

5. Conclusions and discussion

Singh (2001) obtained and examined the series for the frequency of monsoon depressions and cyclonic storms formed over the north Indian Ocean area ($5^\circ \text{N} - 35^\circ \text{N}$, $50^\circ \text{E} - 100^\circ \text{E}$, Bay of Bengal and the Arabian Sea taken together) for 1890-1999 and reported considerable long term downtrends. In the present communication,

- (i) A spectral analysis of the series (one value per year) of the frequency of cyclonic disturbances indicated a highly significant periodicity at $T = \sim 40$ years, and barely significant periodicities at $T = 2-3$ (QBO), 3.7 , 4.6 , 8.8 , and 21.8 years.
- (ii) A spectral analysis of the series (one value per year) of the frequency of cyclonic storms indicated a highly significant periodicity at $T = \sim 37$ years, and significant periodicities at $T = 2-3$ (QBO), 11.4 and 15.4 years.
- (iii) Thus, a strong periodicity at $37-40$ years and some QBO seem to be common features, while storms have additional significant periodicities.



Figs. 3(a-c). Spectra (amplitudes versus periodicities) of the time series of the number of cyclonic storms for (a) yearly values, (b) yearly values detrended, (c) moving averages of detrended values over 5 consecutive years. The hatched portion indicates the 2σ level, and peaks protruding above the hatched area are significant at a 95% level. The abscissa scale is logarithmic, $\log(T)$

The implication of the ~ 40 -year periodicity needs further exploration. The QBO is prominent in low latitude stratospheric winds, while QBO and periodicities near 3.7 and 4.6 years are known to be present in the Southern Oscillation (Tahiti minus Darwin atmospheric pressure) phenomenon (Kane, 1998). It is tempting to attribute the 11.4 -year periodicity of storms to the sunspot cycle. The 15.4 -year periodicity is incognito.

Regarding the long term downtrend in the number of monsoonal cyclonic disturbances and storms reported by Singh (2001), there is an embarrassing dilemma. The downtrends should have affected the rainfalls considerably. However, as shown in Kane (1999), the average (decadal) rainfall in the central part of India changed little (standard deviation below $\pm 15\%$) during 1890-1995, with no significant up or downtrends. However, periodicities of $30-40$ years were seen in Kane (1999), which may be related to the ~ 40 -year periodicity of cyclonic disturbances and storms. Kripalani and Kulkarni (1997) have located epochs of above and below normal rainfall in India as: 1880-1895 (above), 1895-1930 (below), 1930-1963 (above), 1963-1990 (below), but the deviations from the general mean are only a few percent. Thus, the downtrend in the number of disturbances and storms is not reflected in the average rainfall. It seems, therefore that the numbers of cyclonic disturbances or storms are not correlated directly to the rainfall magnitudes. Probably, the intensities of the individual disturbances and storms are of vital importance (a very intense storm may result in more rainfall than several mild storms put together). This needs further exploration.

Acknowledgements

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Comments on the article "Periodicities in the frequency of Indian monsoonal cyclonic disturbances and storms"

1. A low frequency periodicity of about 36 years superimposed on the long-term downtrend in the frequency of monsoonal disturbances is well known (Monsoon rainfall and frequencies of monsoon depressions and tropical cyclones of recent 100 years and an outlook for the first decade of 21st century by Joseph and Xavier in proceedings of TROPMET-99, December 1999, Chennai, 364-371). The downtrend was first reported by Singh (*Mausam*, **52**, 4, Oct. 2001, 655-658) in February, 1999.

2. It is not correct to correlate directly the observed downtrends in the frequency of monsoon depressions and cyclones to the monsoon rainfall over central India. (Dhar *et al.*, 1980; "Is the number of cyclonic disturbances traversing India during monsoon season related to the rainfall in that season?" *Mausam*, **31**, 119-124). It is a common knowledge that monsoon rainfall over central parts of India depends upon the intensity and

location of monsoon trough, number of monsoon lows, depressions and cyclones and their tracks and life spans. Frequent monsoon lows (not necessarily reaching depression stage) with favourable tracks of movement can produce very good rainfall over central parts of India during the monsoon season. Similarly, frequent activation and favourable location of monsoon trough is also capable of producing good rainfall over central parts of India.

3. The speculation made in the last para that the monsoon rainfall may be related to the frequency of intense systems is also not correct. What is required to be explored is the relationship between monthly frequencies, tracks of movement and life spans of all monsoonal systems (lows, depressions and cyclones) with correspondingly monthly monsoon rainfall of some selected sub-divisions of India. A beginning in this direction has already been made by Singh and Mohapatra "(Characteristics of monsoon rainfall over Orissa, to appear in *Mausam*)".

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