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INTRA-ANNUAL QUASI-BIWEEKLY PERIODICITIES OF INDIAN RAINFALL

1. The southwest monsoon is the major rainy season for most parts of India accounting for nearly 75-90% of the annual rainfall. In the southern Peninsula and north-eastern India, the rainfall of pre and post monsoon is also significant. The monsoon exhibits considerable variation from year to year. Apart from this interannual variation, the activity of the monsoon for a given year is interspersed with active and weak spells over a region. Several studies have shown that such intra-annual features of monsoon are not random but possess some regularity. The existence of a biweekly oscillation in some of the monsoon parameters has been brought out by Krishnamurthi and Bhalme (1976), Murakami (1972, 1977) and Keshavamurthy (1973). These studies established the presence of biweekly periodicity in rainfall of central India for the year 1967 and for west coast of India for 1963 and 1971. As rainfall is arguably the most important parameter of monsoon, it was thought desirable to attempt a study on periodicities of Indian monsoon rainfall or more generally Indian annual rainfall for several representative stations of India. The study is based on the long period normal rainfall. Results obtained from analysis of normal rainfall can be, by and large, extended for individual years also. A similar attempt based on normal rainfall in establishing the existence of 30-60 day oscillation in Indian monsoon rainfall has been made by Chowdhury *et al.* (1988).

2. Let $X : \{ x_i, i=1, N \}$, where, $N=365$ be the daily normal rainfall of a station for all the calendar days of the year. Here the i^{th} day denotes the i^{th} day from 1 Jan. To eliminate the low frequency oscillation the series X is smoothed by means of the binomial smoothing function with weights 1, 4, 6, 4 and 1 (Panofsky and Brier 1968) and a new series $Y=\{ y_i, i=1, N\}$ is obtained. We further define $Z_i = y_i - y_{i-1} (i=2, N)$ and $z_1 = y_1 - y_N$. The series $Z=(z_i, i=1, N)$ is the rate of change of daily normal rainfall. The graph of Z has generally several peaks and troughs, which correspond to points of inflexion of the graph of Y. It is reasonable to conclude that the prominent peaks represent an increase of rainfall for individual years also round about the relevant dates and that the deep troughs represent decrease of rainfall.

We intend subjecting the series Z of each station to spectral analysis to detect any hidden periodicity. Though the series Y may not always be stationary, the series Z by and large has a stationary mean. Because of the circular nature of Z we can compute 365 auto-correlation coefficients (CCs) each based on all the 365 values. Let $R_1 = (R_i, i=0, N)$ denote the series of auto CCs of lag 0 to N. As $R_i = R_{N-i}$ we effectively get only 183 CCs, *viz.*, $R_2=(R_i, i=0, M)$; $(M=182)$. The spectral analysis of Z was carried out by following the methodology suggested in Panofsky and Brier (1968) and WMO (1966). The null continuum and hence the 95% confidence limits are to be based on 'Markov red noise' (WMO 1966).

For most stations of India, the Y and hence, Z values differ significantly from 0 only during the southwest

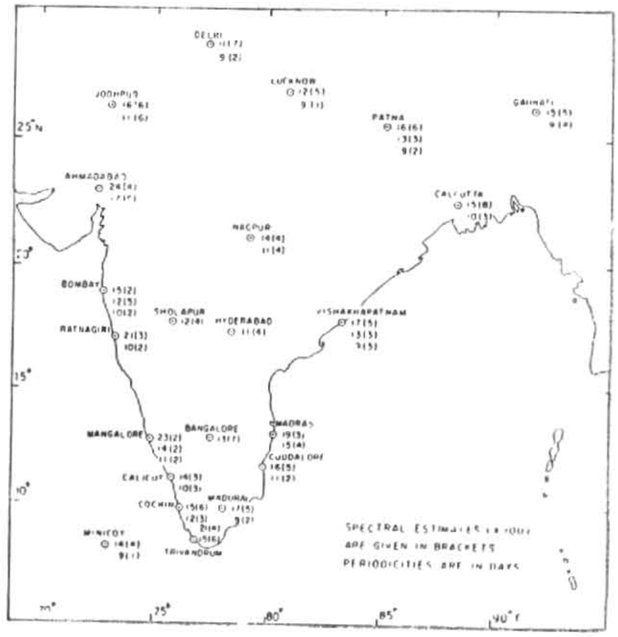

Fig. 1. Stations considered in the study and composite picture of periodicities and spectral estimates of rate of change of daily normal rainfall

monsoon. It can be easily shown that the auto CCs computed from such a truncated series would not differ substantially from those based on the complete series.

3. We chose 22 well distributed stations of India which represent most of the meteorological sub-divisions. Fig. 1 gives the names of the stations considered and also their spatial distribution. India Met. Dep. (1963) gives the cumulative normal rainfall of several stations. From this the rainfall data were extracted. For all the stations considered in this study, the normals have been based on the 50-year period, 1901-50. The daily normals were computed from the cumulative normals and the series Y, Z and R as defined earlier were obtained. The spectral estimates and the 95% confidence limits were computed. Fig. 2 gives the power spectrums of Z along-with the 95% confidence limits for all the 22 stations. The periods corresponding to the prominent peaks of the spectrum have also been indicated in the figure.

From Fig. 2 it can be seen that spectrums of all the stations except Ratnagiri show peak/peaks between 12 and 18 days. A few stations show significant spectral peaks corresponding to periodicities of 20-25 days. Several stations exhibit peaks of periodicities 9-12 days also. Thus, it is concluded that rate of change of daily normal rainfall of Indiam stations exhibits a very prominent biweekly periodicity; besides this some stations do exhibit periodicities of under 10 days or above 20 days. The data on periodicities and the corresponding spectral intensities for each station are given in Fig. 1.

4. The study has brought out that the quasi-biweekly oscillation, which is present in several parameters of the monsoon, manifests itself in rainfall also. This conclusion has been arrived at by subjecting the rate of

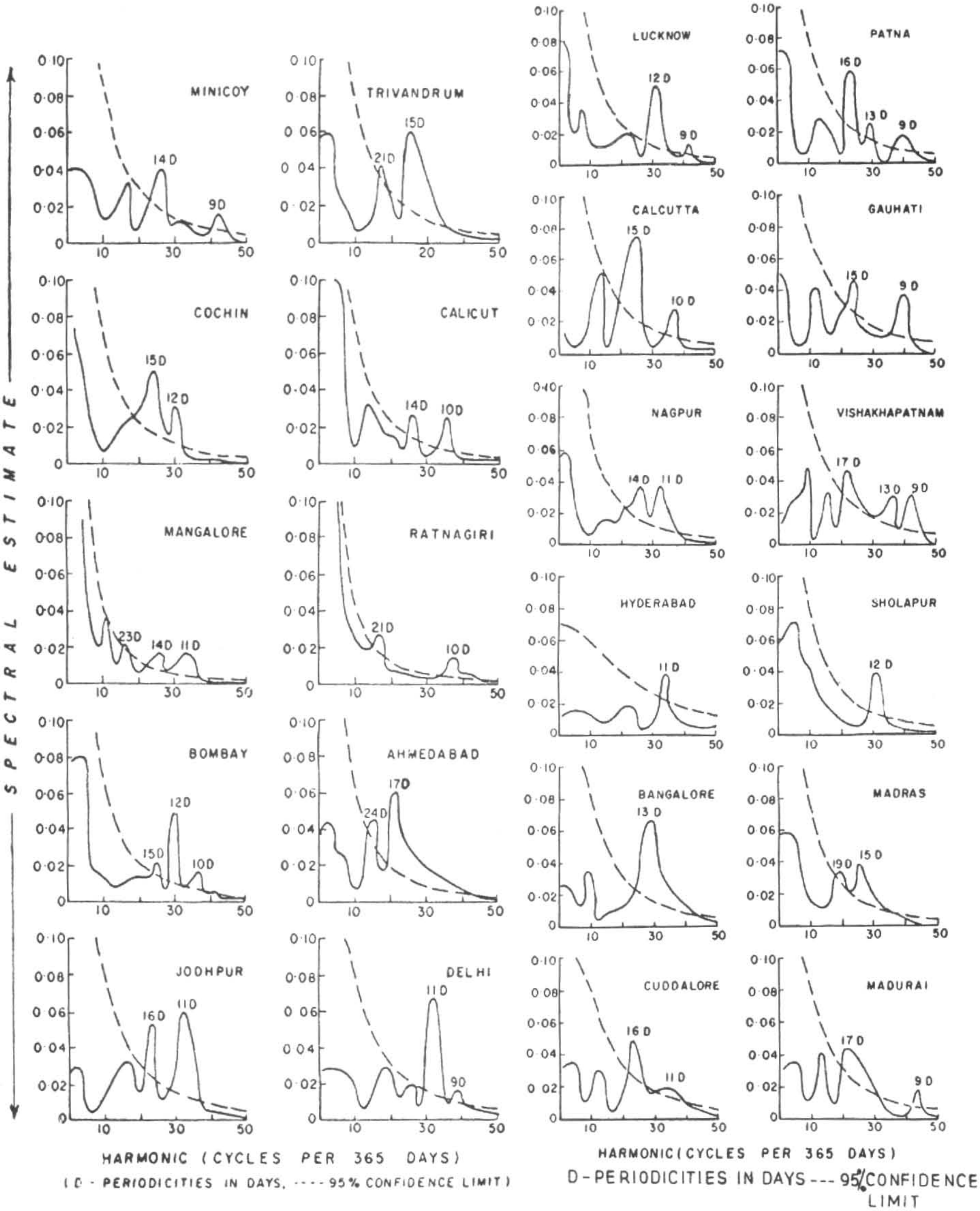

Fig. 2. Power spectrum of rate of change of daily normal rainfall

change of normal rainfall of several stations to spectral analysis. This average feature should be manifested, by and large, for individual years also. Thus, peaks in the rate of change of rainfall graph for individual years which correspond to intense rainfall activity, should have an approximate biweekly recurrence period.

A similar exercise for several stations for large number of individual years should help us in arriving at a complete and detailed picture. The periodicity may vary from year to year but should centre around that obtained from the normal rainfall. Actual daily rainfall of a station for a year may not always show periodicity because of its general non-stationary character. We have used the rate of change of normal rainfall mainly because it is (by and large) stationary. Further, normal rainfall is expected to have very little of 'noise' which rainfall of individual years are likely to possess.

It is seen that rainfall of stations like Cuddalore and Madras for which the post monsoon season of Oct-Dec is the major rainy season, also exhibit biweekly periodicities like other stations. This, perhaps, shows that this feature is common to all the seasons. The biweekly periodicity has the potential to serve as a useful precursor for medium range forecasting of rainfall, aside from the precursors based on synoptic features.

References

Chowdhury, A., Mukhopadhyay, R. K. and Sinha Ray, K. C., 1988, *Mausam*, **39**, 4, pp, 375-382.

India Met. Dep., 1963, *Daily Accumulated Rainfall.*

Keshavamurthy, R.M., 1973, *Indian J. Met. Geophys.*, **24**, pp. 117-124.

Krishnamurthi, T.N. and Bhalme, H.N., 1976, *J. atmos. Sci.*, **33**, 1937-1954.

Murakami, T., 1972, *J. atmos. Sci.*, **29**, 1129-1137.

Murakami, T., 1977, *PAGEOPH*, **115**, pp. 1145-1166.

Panofsky, H.A. and Brier, G.W., 1968, University Park, Pannsylvania, pp. 126-161.

WMO, 1966, *Climatic change*, Tech. Note No. 81.

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