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EQUATORIAL VARIATION OF THE 27-DAY OSCILLATION IN THE HORIZONTAL INTENSITY

B. N. BHARGAVA and D. R. K. RAO
Colaba and Alibag Observatories, Bombay-5, India

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Abstract—Mean daily values of the horizontal intensity for four observatories in the equatorial region of South India have been subjected to spectral analysis. The power densities near the 27-day period have been computed separately for periods of high, moderate and low solar activity. The spectrums indicate that, with decreasing dip, the amplitude of the 27-day oscillation increases during high activity period but it decreases during the low and inclining phase. During the declining phase of moderate activity the amplitude is about the same at all the four stations. The spectrums also show that with solar activity the change in the amplitude of the oscillation is largest near the dip equator, the power density decreasing from the high to the low activity period by a factor of nine.

1. INTRODUCTION

The day-time augmentation of S_q, L and short-period fluctuations such as sudden commencements, sudden impulses, solar flare effects and pulsations in the narrow equatorial belt is well known and has been ascribed to a high ionospheric conductivity in the vicinity of the dip equator. The nature of the enhancement of variations of period from several minutes to a day has been extensively investigated. For short-period variations Mason (1963) noticed that the effective width of the equatorial electrojet decreased with increasing frequency. The nature of equatorial variations of period greater than a day has however remained unexplored. A 27-day oscillation of 4–6 gamma amplitude in the horizontal intensity in the low latitudes is well known and has been associated with solar synodic rotation. The present paper reports the results of a study in the frequency domain of amplitude of this oscillation as a function of dip for periods of high, moderate and low solar activity.

2. ANALYSIS OF DATA

The magnitude of the 27-day oscillation was computed from mean daily values of horizontal intensity at four stations in South India. The geographic coordinates and dip of the stations are shown in Table 1. The series of daily values over a period of 9 yr was divided into three segments one each for high (1958–60), moderate (1961–63) and low (1964–66) activity. The secular, solar cycle, annual and semi-annual variations were eliminated from the series by the application of a zero phase-shift high-pass digital filter. The transfer function of the sine-termination filter (Behannon and Ness, 1966) was within 2·7 per cent of unity for periods less than 45 days. Trend-free series Y_t were computed from the series of mean daily horizontal intensity, X_t, by the linear transformation,

$$Y_t = \sum_{k=-n}^{n} W_k X_{t+k}$$

where W_k is the kth weight of the filtering function and $n = 100$. The filtering process reduced the length of each of the series by 200 points. Following the correlation cosine transformation procedure (Blackman and Tukey, 1959) and the Tukey–Hanning window for smoothing, 136 spectral estimates were computed from each of the three series of 896 trend-free values of mean daily horizontal intensity. The portions of the spectrums corresponding to periods from 54 to 4·5 days are shown for the three periods in Fig. 1. Estimates

TABLE 1

Station	Geographic Lat.	Coordinates Long.	Dip
Trivandrum	08°29′N	76°57′E	S00°·60
Kodaikanal	10°14′N	77°28′E	N03°·37
Annamalainagar	11°24′N	79°41′E	N05°·42
Alibag	18°38′N	72°52′E	N24°·64

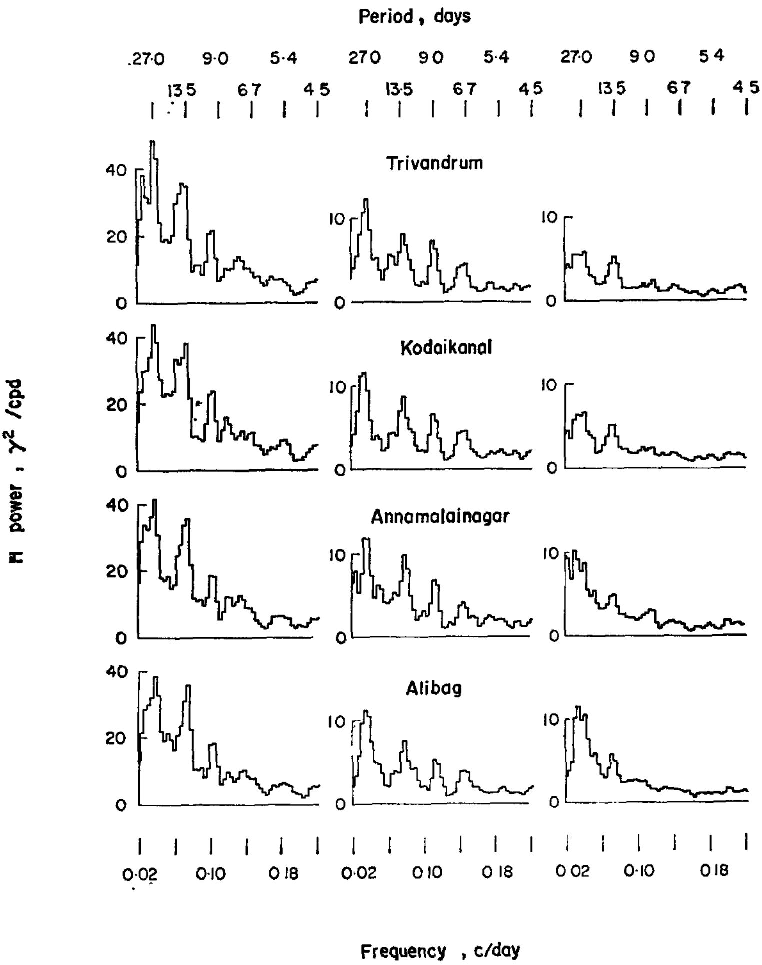

FIG. 1. SPECTRUMS OF SERIES OF MEAN DAILY HORIZONTAL INTENSITY AT THE FOUR EQUATORIAL STATIONS.

The spectrums are for the periods 1958–60 (left), 1961–63 (middle) and 1964–66 (right).

of power at each one of the frequencies, being actually the estimates over a small frequency band, have been shown in the plot by horizontal lines of length equal to the frequency bands.

3. RESULTS AND DISCUSSION

During the high solar activity period the 27-day line is well resolved at all the four stations. In addition to a large peak in power at 27-days, a secondary peak, corresponding to a period of about 38·6 days, appears in the spectrums of two of the four stations. Several harmonics of this line suggest that the peak is real. Most of the other peaks in the spectrums are accounted for by the harmonics of the 27-day oscillation. The fine structure surrounding the 27-day peak is quite complex in all spectrums. High resolution spectrums of indices of magnetic activity often show subsidiary peaks on either side of the 27-day period (Shapiro and Ward, 1966). These have been ascribed to an amplitude modulation of the 27-day solar rotation component by a modulating function of 1-yr period (Coleman and Smith, 1966) but this mechanism has been considered unlikely by Shapiro (1967). Lunar influence (Bell and Defouw, 1966) and periodicites of the order of 29·5 days in the time-series of solar indices (Toman, 1967) have also been suggested to account for the peaks near 29 days. During the low activity period, there is no peak at 27 days but two subsidiary peaks appear near 30 and 24·5 days. This feature has earlier been noticed in the spectrum of the horizontal field at Abinger for 1950–57 (Banks and Bullard, 1966).

Ordinates corresponding to peaks at or near 27-day period have been measured above the continuum and these are listed in Table 2 for the four stations. The power densities

TABLE 2. POWER (γ^2/cpd) IN THE SPECTRUMS OF MEAN DAILY HORIZONTAL INTENSITY

Station	1958–60 ‡$h = 10$	1961–63 $h = 9$	1964–66 $h = 9$	1964–66 $h = 11$
Trivandrum	26·3	7·3*	2·6	3·0
Kodaikanal	20·0	8·4	3·6	3·8
Annamalainagar	18·0	7·2	4·0†	3·6
Alibag	18·3	8·5	7·5	6·7

* Peak power of 8·9 γ^2/cpd appears at $h = 10$.
† Peak power of 5·2 γ^2/cpd appears at $h = 8$.
‡ Period (days) is given by $270/h$.

for the high activity period 1958–60 suggest an enhancement of the 27-day oscillation in a narrow belt in which the two stations closest to the dip equator are situated. For the 1961–63 period the power densities at the four stations near the 27-day period are almost similar. During the low activity and ascending phase, 1964–66, the power density at the three stations, where the dip is 6° or less, the magnitude of the 27-day oscillation reduces as the dip equator is approached. Table 2 also shows that with solar activity the largest decrease in power density near the 27-day period occurred at Trivandrum near the dip equator. From a period of high activity the power density at this station decreased by a factor of about 9 to a period of low activity. The corresponding decrease in the amplitude of the oscillation was therefore by a factor of about 3. At Alibag, where S_q, L and short-period fluctuations are unaffected by the electrojet the corresponding reduction in the power density from high to low activity was by a factor of only 2·6.

The mean daily horizontal intensity, a parameter in which the contribution from the daily variation is reduced, roughly represents the ring-current intensity. The day-to-day variation in the horizontal force has been known to show an association with the interplanetary magnetic field structure (Wilcox and Ness, 1965). Nishida (1966) has shown that the maximum depression in the horizontal intensity occurred about a day after the passage of a sector boundary. In view of the association between the geomagnetic activity and the interplanetary sector structure rotating past the Earth, the solar activity associated change in the power density near the 27-day period by a factor of 2·6 to 9 in the equatorial belt suggests a solar cycle change in the amplitude of variations in interplanetary field magnitude (Wilcox, 1968) and in solar wind velocity.

High activity enhancement of the 27-day oscillation suggests a small but significant enhanced depression during this period in the field near the dip equator. Although the solar daily variation, which tends to increase the mean daily value of the horizontal intensity also increases appreciably from a low to a high activity period, the depression resulting from an enhanced ring-current effect appear to predominate during the high activity period and determines the magnitude of the mean daily horizontal intensity. During the low activity period, however, the solar daily variation appears to predominate resulting in an equatorial decrease in the 27-day oscillation in the horizontal intensity.

The continuum level is the same in the spectrums of the four equatorial stations and the power density towards the high frequency region of the spectrum, ranging from 0·5 to 1·0 γ^2/cpd, suggests a low 'noise' in the series. Near the 27-day period the continuum power density reduces from 20 to 24 γ^2/cpd during high activity to 2·7 to 5·0 γ^2/cpd during low activity. The storm modulation of the field, responsible for the continuum in the spectrum (Eckhardt *et al.*, 1963), therefore, also appears to reduce from the maximum to the minimum activity phase of the solar cycle by a factor of about 2·3.

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