VARIATION WITH LUNAR PHASE OF MIDDAY CRITICAL FREQUENCIES AND HEIGHTS OF THE F2 LAYER OVER AHMEDABAD AND OTHER LOW LATITUDE STATIONS

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Abstract

The paper contains an analysis of the variation of the midday values of foF_2, $h'F_2$ and hpF_2 with lunar phase at Ahmedabad during the years 1954 and 1955 and of foF_2 alone at Bombay, Madras and Tiruchirapalli during 1954. It is found that while the semidiurnal lunar tidal variations at Ahmedabad and Bombay agree in phase with those observed at middle latitudes, the phase reverses in direction between Bombay and Madras. The results are compared with those relating to Huancayo and Singapore.

Introduction

It is known that lunar tidal variations occur in the upper atmosphere as well as in the lower. The amplitudes of variation are much larger aloft and the phases are different. Martyn (1949) studied the F2 layer data of a number of places in middle latitudes and found that the variation was semidiurnal and that the amplitude of variation of foF2 (mean of all hours) range from 0·06 to 0·142 Mc/s and of hpF2 from 1·7 km to 3·6 km. The maximum phases of foF2 and hpF2 were found to be at 10 and 06 lunar hours. Appleton and Beynon (1948) using Slough ($\Phi = 51°$ N) data found the amplitude of lunar variation of foF2 to be 0·05 Mc/s and the maximum phase to be at 11 lunar hours, whereas for hpF2, they found corresponding values to be 2·0 km and 06 lunar hours. The variation at Huancayo as analysed by McNish and Gautier (1949) was different, the amplitude of lunar variation of noon foF2 being as high as 0·4 Mc/s (in sunspot minimum years 1941–44) with the maximum phase at 04 lunar hours. Thus the lunar variation near the geomagnetic equator was apparently higher in amplitude and nearly opposite in phase to that at higher latitudes. However, McNish and Gautier's result was obtained by using only noon values of foF2 while Martyn used the values at all hours. 04 lunar hours corresponds to nearly 4 days before the full-moon day. The occurrence of a phase opposition near the equator was corroborated by Osborne (1952) from his analysis of noon data (1949–51) of Singapore ($\Phi = 10·1°$ S). He found the noon

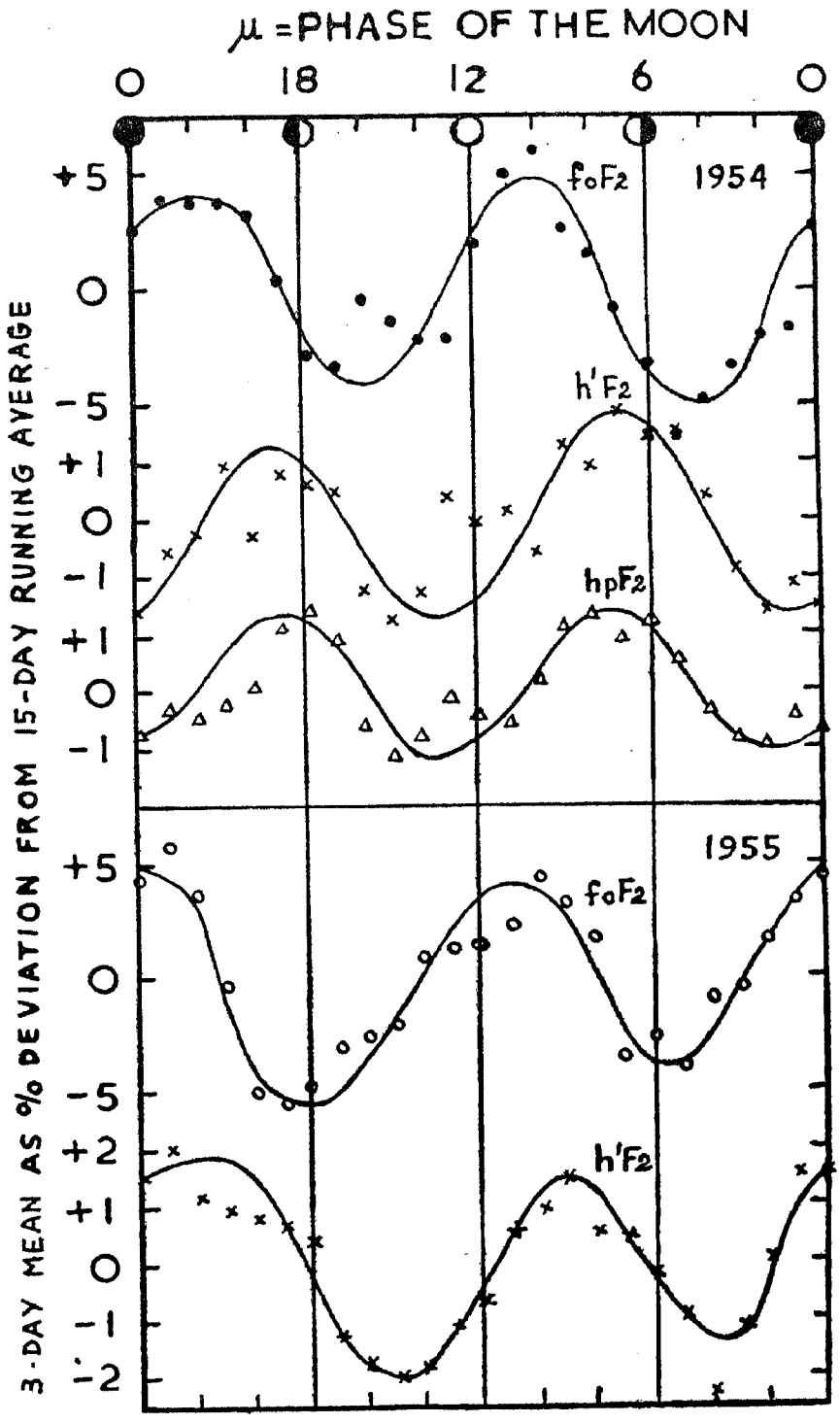

FIG. 1. Variation with lunar phase of midday foF2, hpF2 and h'F2 (10–14 hours) at Ahmedabad in 1954 and 1955.

maxima to occur about four days before full-moon and new-moon days, but the amplitude was slightly less than that at Huancayo. Bartels (1950)

confirmed the variations at Huancayo. His results were expressed as deviations from 27-day running averages. He found that the total change in foF2 due to lunar tide at noon in southern summer was 1·1 Mc/s while in southern winter, it was only 0·2 Mc/s.

ANALYSIS OF DATA AND RESULTS

In view of the above results, it was thought worthwhile to analyse the F2 data collected at Ahmedabad ($\Phi = 13 \cdot 6°$ N). The year 1954 was a minimum sunspot year with a mean sunspot number 4. As this year was almost free from magnetic disturbances, it was considered that 1954 data would be appropriate for analysis of lunar daily variation, when other influences were at a minimum. To start with, the analysis was made of midday foF2, h'f2 and hpF2, taken to be the mean of the values at 10–14 hours. The days in all the months having the same phase (μ) of the moon were grouped together and 24 such groups were obtained for the different phases of the moon. For each phase, the mean midday values (mean of the 5-hourly values at 10–14 hours) for the whole year was found. Whenever there was loss of record or blanketing by Es or failure of equipment, reasonable interpolation was made for the missing value. All the days for which data could be had were taken into account and seasonal changes were eliminated by taking yearly means. The results are given in Fig. 1, which clearly shows that the maximum amplitude occurs about 2 days after the full-moon and new-moon days for foF2 and about 5 days after full or new moon days for h'F2 and hpF2. The results are expressed as percentage deviations of 3-day mean centred at each lunar day from the 15-day running averages. Some points lie outside the curve and these are found to be just those for which the number of observations were few. In terms of lunar time, the phase of foF2 comes out to be 10 lunar hours and that for h'F2 and hpF2 about 07 lunar hours. The corresponding amplitudes are found to be about 4·5% in foF2 and about 1·7% in heights. The results for the year 1955 on the rising part of the solar cycle are shown in the same diagram. The maximum in 1955 has shifted earlier by a day compared to 1954, both in foF2 and h'F2. Fig. 2 gives the mean curves of lunar variation in foF2 and h'F2 for both the years together. The points for each year are marked differently. It will be seen that the phase agrees well with those observed at higher latitudes by Martyn, but the amplitude is larger. One reason for this may be that we have considered midday values only.

It was thought that it would be interesting to examine the lunar variation in foF2 at other Indian stations nearer the geomagnetic equator, *viz.*, Bombay, Madras and Tiruchirapalli. The midday values of foF2 for the year 1954

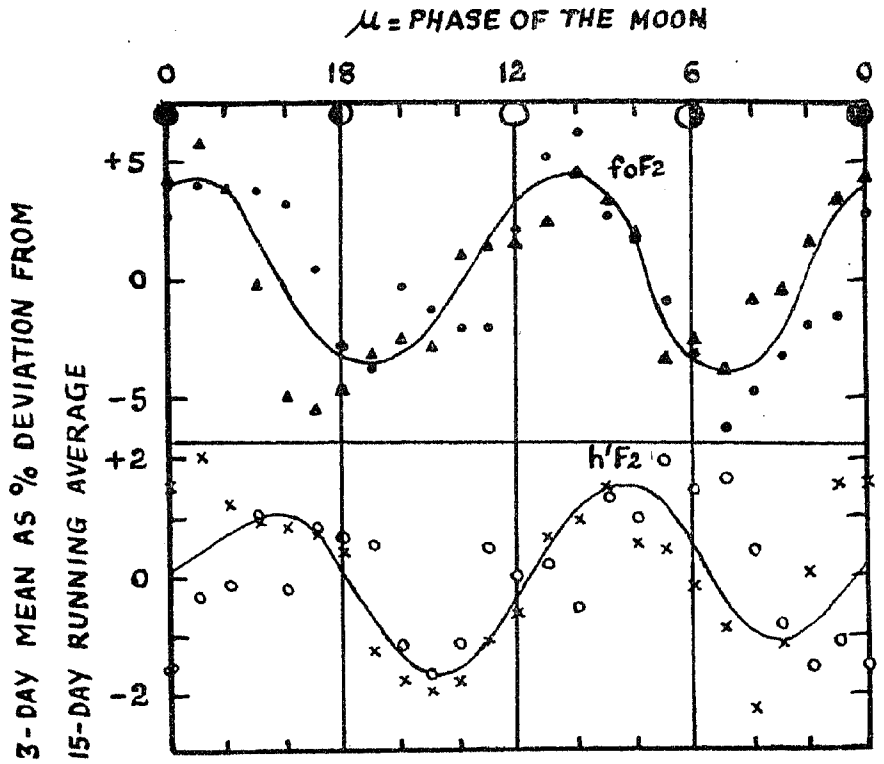

FIG. 2. Variation with lunar phase of midday foF2 and h'F2 (10–14 hours) at Ahmedabad in 1954–1955.

foF2: ···· 1954, ▲▲▲▲ 1955 ; h'F2: oooo 1954, xxxx 1955.

Full line curve is the mean for 1954–55.

at the above stations collected by All-India Radio were analysed in the same manner, and the results are given in Fig. 3. It is interesting to note that the phase at Bombay ($\Phi = 9{\cdot}5°$ N) is practically the same as at Ahmedabad, whereas at Madras ($\Phi = 3{\cdot}1°$ N), the phases are almost opposite. This shows that north of equator, a phase-reversal takes place somewhere between 9·5° N and 3·1° N geomagnetic latitude. Tiruchirapalli which is still near the equator has a maximum about $2\frac{1}{2}$ days before full or new moon as against about $3\frac{1}{2}$ days at Madras. Another point is that instead of an increase in amplitude towards the equator as observed by others, we find that the amplitude decreases after reaching a maximum. Observations at Ahmedabad were made with an automatic ionospheric recorder whereas at the other places they were made manually. The accuracy of reading in foF2 was 0·1 Mc/s at all the places.

It is interesting that although Bombay has nearly the same geomagnetic latitude to the north of the geomagnetic equator as Singapore is to the south, there is a difference between the lunar variations at the two places. While the equatorial type of variation is observed at Singapore, the middle

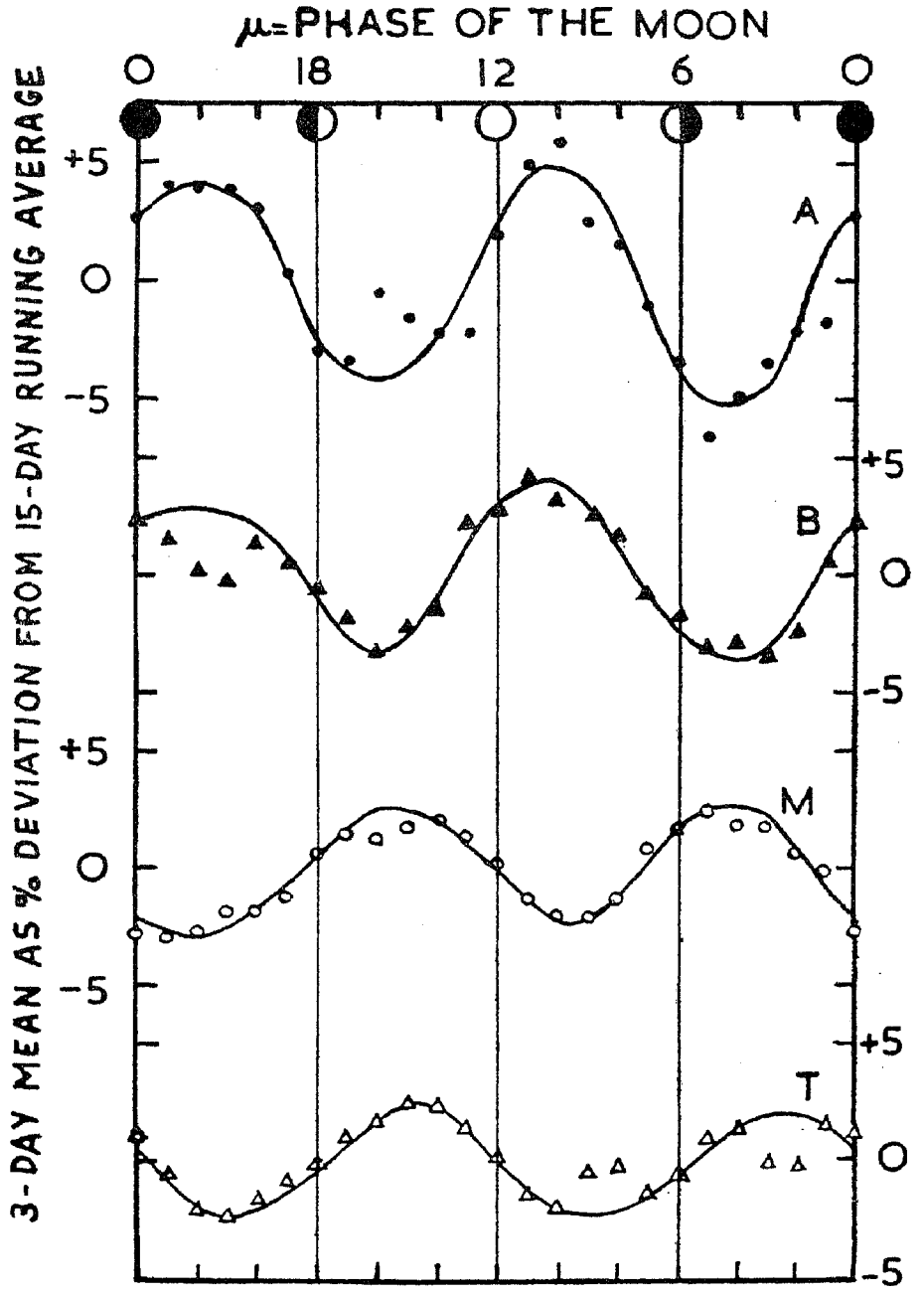

FIG. 3. Variation with lunar phase of midday foF2 (10–14 hours) at different latitudes in 1954. A: Ahmedabad, B: Bombay, M: Madras, T: Tiruchirapalli.

latitude type occurs at Bombay. The change to the equatorial type occurs between Bombay and Madras, perhaps nearer Bombay than Madras. Singapore is however only 1° 19′ north of the geographic equator.

To facilitate ready reference, the results of the analysis of the second harmonic components for 1954 are collected in Table I below; those of Singapore relate to 1948–51 and of Huancayo to 1941–44.

TABLE I

Amplitude P2 and Phase t2 of lunar Variation in foF2

Place	Geomag. lat.	foF2			hpF2	
		100P2 mean foF2	P2 Mc/s	t2 lunar hours	P2 km	t2 lunar hours
Ahmedabad ..	13·6° N	3·9	0·35	10·2	3·0	7·2
Bombay ..	9·5° N	2·6	0·24	10·0	..	..
Madras ..	3·1° N	1·8	0·14	3·8	..	..
Tiruchy ..	1·3° N	1·8	0·13	2·8	..	..
Huancayo ..	0·6° S	5·0	0·40	4·0	..	..
Singapore ..	10·1° S	(3·0)	(0·30)	(4·0)	..	..

The non-agreement of the results of Bombay and Singapore suggests that the lunar variation does not depend on geomagnetic latitude only. If we consider two stations according to geographical latitudes, Bombay (geogr. lat. 19° N) falls in the middle latitude group while Singapore (geogr. lat. 1·3° N) is in the equatorial group.

Bartels has shown that at Huancayo, the total change of noon foF2 during a lunar cycle in southern summer is nearly 5 times that in southern winter and Burkard (1951) has shown that the semidiurnal lunar variation of foF2 is pronounced during the daytime only and practically absent during the night. The significance of the phase-reversal of the lunar semidiurnal variation between the latitudes of Madras and Bombay and at some latitude to the south of Singapore remains to be explained. An analysis of the available Indian data to study the lunar variations in different seasons of the year is being undertaken.

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