Lunar Phases and Atmospheric Electric Field

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Received February 23, 1988

ABSTRACT

The association between the lunar phases and the atmospheric electric field has been investigated from the superposed epoch analysis of the long series of continuous data of the vertical electric field for Colaba, Bombay (18° 53′N, 73° 48′E 11 mASL) for the period 1947–1966. Also the periodicities in the atmospheric electric field have been studied from the spectral analysis of the data. The study has indicated that when the full moon is within 4° of the ecliptic plane i.e., $B_l \le 4°$, the electric field peaks on the day of the full moon followed by a steep fall in the field values up to 4 days following the full moon day and there after it showed a steep increase. Also, the electric field has exhibited 5–9 day periodicity and its multiples are nearly always present. The periodicity in the electric field corresponds with the average time interval between the successive magnetic sector boundary (MSB) crossings i.e., 7 days. On most of the occasions, the MSB crossing day is associated with a maximum of one or more of the wavelengths derived from the spectral analysis of the atmospheric electric field

I. INTRODUCTION

In the search for physical mechanisms linking solar activity to weather, other possibly obscuring influences with periodicities of lengths similar to those of solar periodicities should be considered (Herman and Goldberg, 1978). The lunar sidereal period of 27.3 days, for example, is almost the same length as the average solar rotation period of 27 days. There have been many reports of lunar influence on weather (Markson, 1971). The lunar synodic period of 29.5 days, from new moon to the next new moon, is considered to be a more appropriate periodicity to study than the sidereal period measured with reference to the stars.

As several meteorological phenomena are known to be related to geomagnetic activity, there could be an apparent lunar influence on weather if the phase of the moon were in some way related to geomagnetic activity. The idea that the phase of the moon might have an effect on geomagnetic activity seems to have been introduced by Wulf and Nicholson (1948), who found that recurrent magnetic storms might be related to lunar declination. In 1964, Stolov and Cameron, using rigorous statistical techniques, showed that the K_p values consistently decreased by about 4%, 7 days preceding the full moon and increased by about 4% at about full moon phase and continued for another 7 days. In 1965, Stolov was able to show that the lunar modulation of geomagnetic activity takes place when the Moon is within 4° or less of the ecliptic plane and within the tail of the magnetosphere. There was no apparent effect with the Moon in its other phases. This led Stolov to postulate a physical mechanism for the lunar modulation effect, and reiterated by Markson (1971). According to them, when the Moon is lose to the ecliptic at full phase, it will be in the then newly discovered neutral sheet of the nagnetotail. The neutral sheet, being inherently unstable, might be perturbed by the Moon in such a way that magnetic field annihilation would accelerate particles toward the Earth. These particles, entering the ionosphere, could produce currents that would in turn perturb the Earth's magnetic and electric fields. Support for the above postulation and an amplification of it have been given by Bell and Defouw (1966). Principal results of their superposed epoch analysis of daily K_p sums for the period 1932–1962 show significant enhancement of K_p for several days following full moon, within 4° of the ecliptic.

A number of theoretical studies have indicated that the geomagnetic tail should reach the neighbourhood of the moon's orbit or beyond (Piddington, 1960; Axford, 1962; Dessler, 1964; Dungey, 1965). Observations by the satellite IMP 1 support this expectation (Ness, 1965). IMP 1 observed the geomagnetic tail as far out as its apogee distance of approximately 30 earth radii (about half the distance to the moon's orbit). At this distance, the diameter of the magnetosphere was found to be 40 earth radii, and the data gave no indication of an end to the earth's tail, which may therefore be reasonably assumed to extend as far as the moon's orbit Ness concluded "the moon always crosses the earth's magnetic tail and hence luknar related phenomena in the magnetosphere and on the terrestrial surface can be expected".

Studies relating to the association between the lunar phases and the atmospheric electric field observations in the Indian region are not reported in the literature. Hence the above study has been undertaken using the long series of continuous data set of the atmospheric electric field available for Colaba, Bombay (18° 53′N, 72° 48′E, 11m ASL) for the period 1936–1966. It was also thought worthwhile to investigate the periodicities in atmospheric electric field that may correspond to the rotation of interplanetary magnetic field. This study is mostly statistical in nature. However, the results may have some significance in viewing the problem in a new perspective which attempts to correlate the periodicities present in atmospheric electric field with the co–rotating sector structure of interplanetary magnetic field. The results of the above studies are presented below.

II. DATA AND ANALYSIS

(1) *Lunar phases and atmospheric electric field*

In the present study, atmospheric electric field data for Colaba, Bombay (18° 53′N, 72° 48′E, 11 m ASL) for the period 1936–1966 have been analysed with respect to the full moon phase by the method of superposed epoch analysis. The full moon dates were taken from the Nautical Almanacs published by Her Majesty's Stationary Office (1936–1959) and Government of India Press (1960–1966). The full moon days were classified according to the celestial latitude B_f of the full moon, without regard to the sign. The subdivisions were made as B_f 1°, 1° B_f 2°, 2° B_f 3° and B_f 4°.

The atmospheric electric field data derived at four distinct hours every day i.e., 02–03, 08–09, 14–15, 20–21 hours IST were used for the study. The electric field data were published by the India Meteorological Department and these data are available only for the four distinct hours mentioned above. As the original recordings are not available, the present study could only be undertaken with the available data for the four fixed hours of the day. Use of the data derived at the fixed hours of the day may avoid the possible effects of diurnal variation on the results obtained from the present study.

(2) *Spectral analysis of electric field*

Standard method of spectral analysis has been used. 0–249 wavelengths were taken with a tuning of 0.02. Only that atmospheric electric field data which did not have a break of more than two consecutive days were utilized for the analysis. Also, if the observations were missing on more than 30% of the days of any season, the data set for the entire season was rejected. For the data sets used for analysis,. missing values of atmospheric electric field were substituted by the mean value of the atmospheric electric field for that particular month. Also. the extreme values of atmospheric electric field recorded on days of disturbed weather conditions were deleted from the data set used for the analysis. This would. by and large, eliminate the possible local effects on atmospheric electric field arising out of extreme meteorological and environmental conditions.

The periodograms obtained from the spectral analysis of the atmospheric electric field data were examined to select wavelength ranges whose normalized variance was greater than 2.0. Wavelengths were categorized into the following groups (1) 5 days, (2) 5–9 days, (3) 10–19 days, (4) 20–25 days, (5) 26–30 days and (6) 30 days.

III RESULTS AND DISCUSSION

1 *Lunar Phases and Atmospheric Electric Field*

The mean pattern of the normalized electric field variations during a 13–day period centered around the full moon date is shown in Fig.1. The results show that in the 6 days preceding the full moon day, for which B_r 4 °, the electric field increases and reaches a peak on the day of the full moon. There is a steep fall in the values of electric field up to 4 days following the full moon day, after which the electric field rises again. The physical mechanism for the observed increase in the electric field for the secondary maximum around 6 days following the full moon are not clear. However, one of the possible explanations is given below. Markson (1971) hypothesized that the magnetohydrodynamic wake of the Moon (analogous to Earth's magnetotail) produced by the solar wind, interacts with the Earth's magnetotail, or perhaps, modulates the flow of solar particles to the tail. This lunar–perturbation–of–the–magnetotail hypothesis results in lunar modulation of geomagnetic activity. The above hypothesis is corroborated by the results of the study by Stolov (1965) and Bell and Defouw (1966). The study by Bell and Defouw suggests that the rise in the level of geomagnetic activity a few days (4–5) after low latitude full moon could be due to lunar modulation of geomagnetic activity arising from the interaction of the Moon with the Earth's magnetotail as explained by Markson (1971). Considering that the above physical hypothesis is possible, the increase in the electric field after the full Moon could be attributed to the lunar modulation of geomagnetic activity since geomagnetic activity is known to influence electric field.

The electric field variations for the four subdivisions of B_r are shown in Figure 2. The electric field variations follow the same pattern as in Figure 1 for all the subdivisions of B_r, except that there is a difference in the amplitude of oscillation.

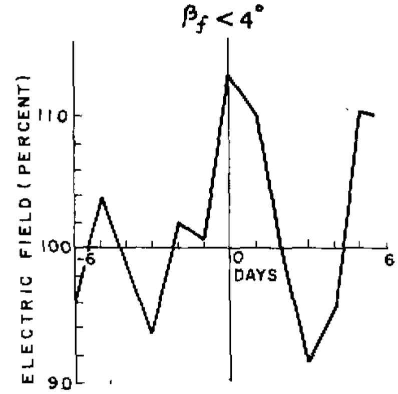

Fig.1. Average pattern of superposed epoch analysis of fair weather atmospheric electric field recorded at Alibag on days surrounding full moon as day zero (1936–1966).

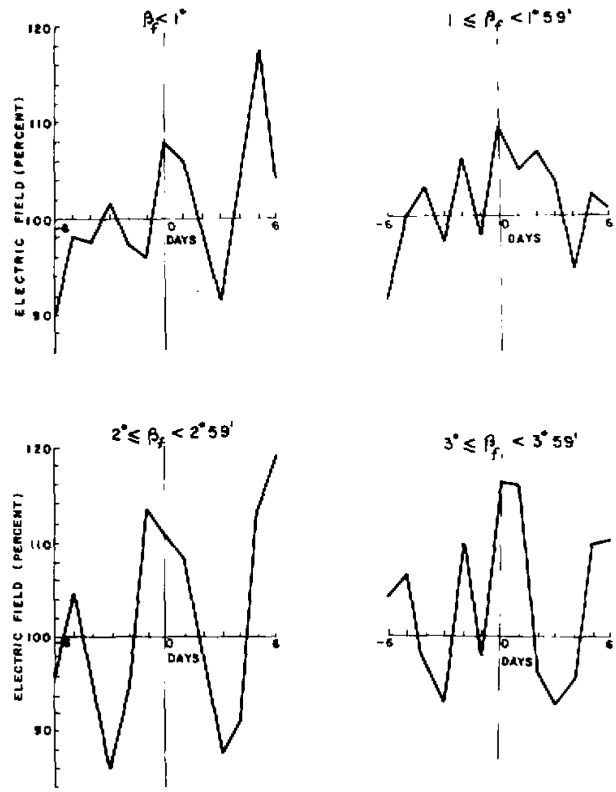

Fig.2. Superposed epoch analysis of fair–weather atmospheric electric field recorded at Alibag on days surrounding full moon as day zero (1936–1966).

2. *Spectral Analysis of Atmospheric Electric Field Data*

The results of the spectral analysis of atmospheric electric field data are shown in Tables 1–4 and Fig. 3.

The results indicate the presence of periodicities of 5 to 9 days and its multiples in almost all the sets of data analysed (Tables 1, 2, 3, 4). Since the interplanetary magnetic field in general. has four sectors corresponding to one complete rotation interval of the sun (about 27 days), the average time interval between any two successive sector boundary crossings is expected to be about 7 days. This period is almost the same as the periodicities found in the electric field. Figure 3 shows a representative periodogram. The 5–9 days periodicities and its multiples are seen with slight shift towards smaller or higher wavelength. This wavelength shift may be due to varying time intervals between the successive MSB crossings.

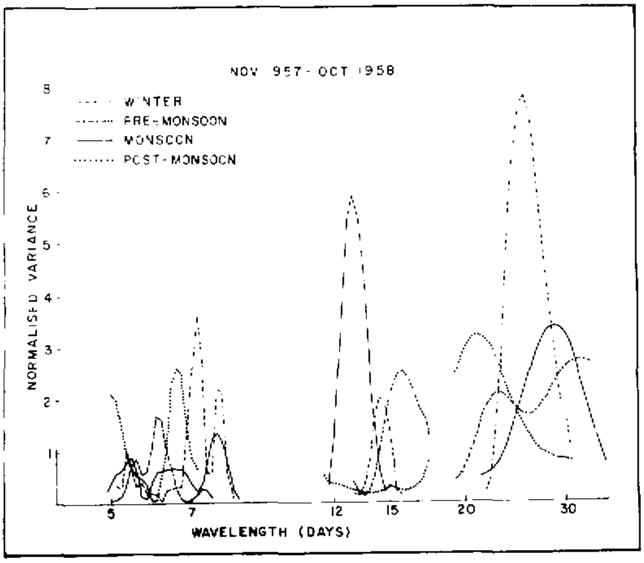

Fig.3. Periodicities (in days) observed in the electric field data recorded at Alibag.

Further, the atmospheric electric field data were also examined to see whether any of the wavelength maxima occurred within ± 2 days of any MSB crossings. On most occassions it is found that MSB crossing day is clearly associated with the time of occurrence of the maxima of one or more of the wavelengths derived from the spectral analysis.

Table 1. Significant Periodicities (in days) at less than 5% significance Level for Winter (November–February) for the 4 Fixed Hours of Obbservation

Year	5 days	5–9 days	10–19 days	20–25 days	26–30 days	30 day
1936	4	5.8			27.29	86
1937	2	5				34,123
1938	1	7	11,18		27	97,88
1940	3.4	7				34,80
1942			13	25		
1943			15,17,10.13.16	25		63.51,126.54,70
1945				20		52,47,65,49
1947	4.3	8.9		21		
1048	2	6.8		22	30	36,127,101
1949			10,15			94
1953			17			
1955			11,16			52.116,50.126
1956				21		150,32.150
1957	4,3	8	10,18			36,114,153,54
1958				20	26	45.166,147,180
1959	4,2,3	6,8	12,18		29,26	43,72
1964	2.3	9,5	10,11.12	25		150
1965		7	15.10			88.93,87,86
1966	3		12,10		30	65

Table 2. Same as Table 1 for Pre–monsoon (March–May)

Year	5 days	5–9 days	10–19 days	20–25 days	26–30 days	30 days
1936		7.9				39.87.70,116
1937	2.3		13	21		99
1938					27	128
1941			10,19			
1945	4		14			99,126,35,37,82
1948	3	6,8				35,131,66,53
1949	3	5,6	10			127,88
1952	4	8,9	15.14			45,128,49,141
1953		5,7		22		116.126.49
1956	2	9,7	10			43,45,139,79
1958	4	5,9	15			129
1959	3,4	9	17,16	22		131.54
1961		6.5.9	17,18			123.50.150.57
1962	3	6,7	16	22,23	27	133
1965	2.4	8				
1966		5	19	25	27	70,50.144,84.49

Table 3. Same as Table 1 for Monsoon (June–August)

Year	5 days	5–9 days	10–19 days	20–25 days	26–30 days	30 days
1936	3	5				37,88,39,78
1937	2	7				38.76
1938	4	9	14,10		27	123
1939	3		11		27	45.48
1948	3	7				49.88
1957	3					131
1961	3	6.5	17	23,24		61,66.50
1966	3				28	37,76.81.83.79

Table 4. Same as Table 1 for Post–monsoon (September–October)

Year	5 days	5–9 days	10–19 days	20–25 days	26–30 days	30 days
1936			12,19,10		30	88
1937		8	13			91
1938						32,81
1940						52
1942	3.2	6		20.21		86.93
1948		5	13.16			55,74,44
1952	2	6				36
1953	3	5	12	21	27	45
1955	3	7				54
1956	4		19			83.86
1958	4	5.10	15			128
1959		5		21,22		88,95.53
1961		7,8	10			86.88
1965			11			34
1966	3	6,7	12			84.32.81

IV. CONCLUSION

The study of the response of the atmospheric electric field to lunar phases and periodicities of atmospheric electric field suggests the following:

(1) For B_i 4° . the atmospheric electric field reaches a peak on the day of the full moon after which there is a steep fall in the field values up to 4 days following the full moon, followed by a steep increase in the atmospheric electric field.

(2) Periodicities of 5–9 days and its multiples are nearly always present. This period is almost the same as the average time interval between two successive sector boundary crossings i. e., 7 days .

(3) On most occassions it is found that MSB crossing day is clearly associated with the time of occurrence of the maxima of one or more of the wavelengths derived from the spectral

analysis.

The author wishes to express her sincere thanks to Dr. A. M. Selvam and Dr. A. S. R. Murthy for giving their valuable suggestions and encouragement during the period of this study.

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