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Lunar and Solar Geomagnetic Tides in the Geomagnetic Equatorial Region—

II Geomagnetic Tidal Variations at Alibag

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(*Received 16 March 1961*)

ABSTRACT. The lunar and solar geomagnetic tides at Alibag are determined by the fixed age method following the Chapman-Miller technique, for the three seasons—December solstice, equinoxes and summer solstice. The seasonal variation in the amplitudes and phases of $L(H)$ are compared with similar results for Kodaikanal, Huancayo and Ibadan. Confirmation has been obtained for an earlier suggestion of the author that the southern hemispheric currents in ionosphere which cause L variations extend upto 10°N geomagnetic latitude in December season. The nature of the seasonal variations of $L(H)$ at Alibag is the same as that at Ibadan, and different from what is obtaining at Kodaikanal and Huancayo.

1. Introduction

In an earlier paper (Raja Rao 1961) afterwards referred to as I, the major features in the lunar and solar geomagnetic tides at Kodaikanal, very close to the geomagnetic equator, have been described. Large tidal variations—both solar and lunar—have been found to occur, similar to the variations at Huancayo. Also it was found that in Kodaikanal, just as in Huancayo, the amplitude of the principal lunar component, *viz.*, the second component, is larger in the December solstice than in the June solstice, although Kodaikanal and Huancayo are on opposite sides of geomagnetic equator. Based on comparative study of tidal variations at Ibadan, suggestion was put forward in I that the southern hemispheric current system extends upto about 10°N geomagnetic latitude. In order to put this suggestion to test, the lunar and solar tidal variations have been determined for Alibag (Geomagnetic latitude 9°·5 N, Geographic latitude 18°·3 N).

2. Lunar tidal variation from geomagnetic data

The data examined consist of the hourly values of horizontal intensity of the Earth's magnetic field recorded at Alibag during the period 1950-54. The method used in the analysis is based on the mathematical development of Chapman and Miller (1940).

The lunar geomagnetic tides have been determined for Alibag for the three seasons—the December solstice (November, December, January and February), equinoxes (March, April, September and October) and the June solstice (May, June, July and August). The tides have been determined up to four harmonics and their amplitudes (L_1, L_2, L_3 and L_4) and phases (λ_1, λ_2, λ_3 and λ_4) have been given in Table 1.

3. Lunar variations : Discussion of results

No pronounced tidal variations have been found in the first, third and fourth harmonics. The second harmonic shows a well marked daily variation. Harmonic coefficients of the second component (amplitude in γ) and the time of maximum amplitude in lunar hours reckoned from local transit of the mean moon are displayed in the usual manner on the 12-hourly harmonic dial (Fig. 1).

The filled circle stands for December solstice, the cross for the equinoxes and the open circle for the June solstice. The probable errors calculated according to the method

TABLE 1

Amplitudes and phases of lunar harmonics at Alibag 1950-54 (Amplitudes are expressed in γ)

Season	L_1	λ_1	L_2	λ_2	L_3	λ_3	L_4	λ_4
December solstice	0·41	—22°34′	1·27	+214°28′	0·62	4°38′	0·14	—106°30′
Equinoxes	0·71	—17°08′	1·07	+170°32′	0·52	—17°22′	0·12	—233°28′
June solstice	0·78	—17°36′	1·02	+203°27′	0·70	—13°27′	0·28	—60°28′

TABLE 2

Amplitudes and phases of solar daily variations at Alibag (Amplitudes are expressed in γ)

Season	S_1	σ_1	S_2	σ_2	S_3	σ_3	S_4	σ_4
December solstice	10·8	—69°32′	6·8	—77°14′	2·0	—196°06′	0·7	—217°46′
Equinoxes	17·0	—70°40′	9·0	—102°31′	2·9	—209°18′	0·8	—275°08′
June solstice	12·3	—67°51′	7·1	—80°00′	2·3	—183°54′	0·8	—258°49′

given by Tschu (1949) and Chapman (1952) are depicted as circles whose radii are equal to the probable error.

At Kodaikanal the amplitude L_2 is larger in the December than in the June solstice by a factor of 2·3 and in Ibadan (geomagnetic latitude 10°·5N) it is larger by a factor of 1·4, while at Alibag the ratio of winter to summer amplitudes is 1·2. This factor decreases as the distance from the geomagnetic equator increases.

The phase of the second harmonic decreases from December to June by 35° in Kodaikanal, while at Alibag, there is no marked change in phase, Onwumechilli and Alexander (1959) did not find any marked change in phase at Ibadan, from winter to summer. Thus Ibadan and Alibag show similar variations in the principal lunar component; although their geographic latitudes differ by 12°. Thus it has been found in the course of the present work that the anticipations mentioned in I are borne out and in consequence it has been possible to draw certain conclusions regarding the lunar geomagnetic tidal variations in the low latitude region.

4. Lunisolar variations

As stated earlier, only the first four harmonic components of L are determined; L_4 is small and it can reasonably be assumed that L_5, L_6 ......are negligible.

The lunisolar components are small in comparison with the purely lunar component L_2. The phase in $L_1(H)$ decreases from winter to summer by about 50° in Kodaikanal while at Alibag there is an increase in phase by about 110°. But the amplitude also increases from winter to summer at Alibag while it decreases at Kodaikanal. At Ibadan there is an increase in the phase of $L_1(H)$ from winter to summer by about 60° with an increase in amplitude just as at Alibag.

In L_3 (H) there is an increase in amplitude and a decrease in phase by about 20° from winter to summer. At Kodaikanal the phase increase is by 176°, with the increase in amplitude, while at Sitka (geomagnetic latitude 60°N) the phase of L_3 (H) decreases from winter to summer by about 160° with an increase in amplitude. At Ibadan, there is a slight increase in

TABLE 3

The ratio $S_1(H)/L_2(H)$ for the three seasons at the low latitude observatories

Station	Season		
	December solstice	Equinoxes	June solstice
Huancayo	5·1	8·8	16·5
Kodaikanal	6·0	10·7	15·8
Ibadan	8·3	12·1	10·8
Alibag	8·3	15·4	12·1

phase by about 150° in L_3 (H) and decrease by 150° in $L_4(H)$. Both at Alibag and Ibadan, the amplitudes of $L_3(H)$ and L_4 (H) increase slightly from winter to summer.

Thus the seasonal variations in the lunar and lunisolar components at Alibag and Kodaikanal are not similar although they differ only by 9° in geomagnetic latitude. The anomalous nature of the L variations near the geomagnetic equator must, therefore, be confined to a very narrow belt along the geomagnetic equator. However, the Alibag results compare well with the results for Ibadan. The geomagnetic latitudes of the two stations differ only by one degree. This indicates a geomagnetic control of the L field. For, the amplitudes of the lunar components are more closely related to the geomagnetic latitude than to the geographic latitude. Although Kodaikanal and Ibadan are on nearly the same geographic latitude and Ibadan and Alibag on nearly the same geomagnetic latitude, the features of the L field at Ibadan bear similarity to the L field at Alibag more than to that at Kodaikanal.

5. The solar daily variations

$S(H)$ has been worked out for Alibag upto four harmonics for the December solstice, equinoxes and the June solstice. The amplitudes S and the phases σ are given in Table 2.

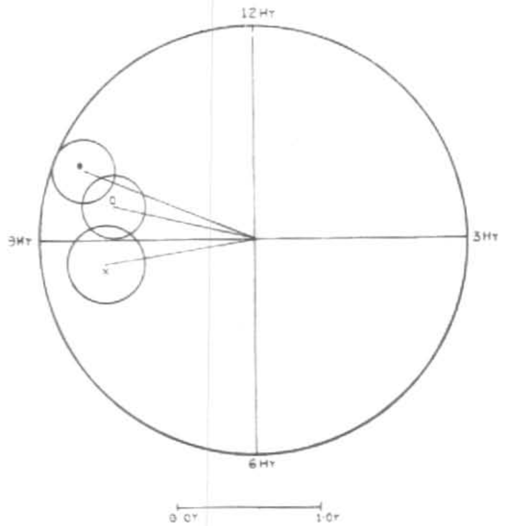

Fig. 1. Harmonic dial for semi-diurnal Lunar variation in horizontal intensity at Alibag, 1950-54

The first harmonic $S_1(H)$ is the most dominant one. It has nearly the same magnitude in the December as in the June solstice. There is no significant change in phase either. Similar results were obtained for Kodaikanal in the earlier studies in I. But the amplitude of $S_1(H)$ at Kodaikanal is far greater than that at Alibag due to the proximity of Kodaikanal to the electrojet. The ratios $S_1(H)/L_2(H)$ or the ratios of the dominant solar harmonic to the dominant lunar harmonic for stations Kodaikanal, Huancayo, Ibadan and Alibag are given in Table 3.

A study of Table 3 reveals that while Kodaikanal and Huancayo show systematic increase from the December solstice to equinox and then to the June solstice, Alibag and Ibadan show a different type of variation, *viz.*, largest value in the equinoxes and least value in December.

6. Conclusion

The study of the lunar and solar daily variations at Alibag, in comparison with similar variations at other geomagnetic equatorial stations confirms the earlier suggestion of the author in I that the seasonal variations in $L_2(H)$ upto 10°N geomagnetic latitude is similar to the variations just to the south of the geomagnetic equator. The present study lends further support to the suggestion that the southern hemispheric currents in the ionosphere, which cause the lunar geomagnetic variations, extend upto 10°N geomagnetic latitude. The seasonal variations in the lunar and lunisolar harmonics—both amplitudes and phases—at Alibag and Ibadan which have nearly the same geomagnetic latitude are identical, and they differ from the variations at Huancayo and Kodaikanal which between themselves exhibit good agreement indicating a geomagnetic control of the L field.

7. Acknowledgement

I wish to express my gratitude to the Director General of Observatories, New Delhi for permitting me to use the unpublished hourly values of horizontal intensity at Alibag for the period 1950–54 and granting me study leave which enabled me to undertake the present investigation.

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