

# Lunar and Solar Geomagnetic Tides in the Geomagnetic Equatorial Region—

## III Geomagnetic Tidal Variations at Apia

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**ABSTRACT.** With a view to find out the characteristics of lunar and solar geomagnetic tides in the low latitude region in the southern hemisphere, the geomagnetic data of Apia have been analysed. The seasonal variation in the amplitudes and phases of the lunar and solar geomagnetic tides have been studied. These variations are compared with the variations at Alibag, and at Huancayo. Comparison with the latter indicates geomagnetic control of the  $L$  and  $S$  variations.

### 1. Introduction

In the earlier papers (Raja Rao 1961, 1962) afterwards referred to as I and II, study has been made of the major characteristics of the lunar and solar daily variations in the geomagnetic field at Kodaikanal very close to the geomagnetic equator (I) and Alibag, a low latitude station not close to the geomagnetic equator (II). Kodaikanal shows characteristics very similar to Huancayo on the opposite side of the geomagnetic equator, with large amplitudes—both lunar and solar—in the geomagnetic tides. The seasonal variation was also similar. Based on the comparative study of the seasonal variations of the  $L$  field at Ibadan and Kodaikanal, a suggestion was put forth in I that the southern hemispheric currents in the ionosphere causing  $L$  magnetic tides extend up to about  $10^{\circ}$ N geomagnetic latitude in northern winter. It has been shown in II that this anticipation has borne out, as a result of the study of the Alibag data. The seasonal variations of the lunar and luni-solar harmonics at Alibag and Ibadan are comparable, their geomagnetic latitudes being  $9^{\circ}\cdot5$  N and  $10^{\circ}\cdot5$  N respectively.

In order to study the nature of solar and lunar daily magnetic variations at a station which may be considered the southern counterpart of Alibag—just as Kodaikanal is the northern counterpart of Huancayo—the

lunar and solar geomagnetic tides have been determined for Apia.

### 2. Lunar tidal variations

Apia is the only magnetic observatory in the southern hemisphere in the low latitude region currently functioning, apart from Huancayo. The co-ordinates of Apia are—

Geographic latitude	$13^{\circ}\cdot8$ S
Geographic longitude	$188^{\circ}\cdot2$ E
Geomagnetic latitude	$16^{\circ}\cdot0$ S
Geomagnetic longitude	$260^{\circ}\cdot2$ E
Magnetic latitude	$30^{\circ}\cdot0$ S

The hourly values of the horizontal intensity of the geomagnetic field at Apia for the period 1950–54 have been extracted from the published Annual Volumes of the Apia Observatory. The analysis has been done according to method developed by Chapman and Miller (1940).

The lunar geomagnetic tides have been determined for the three seasons—December solstice, equinox and June solstice, up to four harmonics. The amplitudes and phases of the four harmonics are given in Table 1.

### 3. Discussion of Lunar Geomagnetic Tides

At Apia, as at any other station the dominant harmonic is the second one. First and third harmonics are nearly equal to each other

TABLE 1  
Amplitudes in  $\gamma$  and phases of the first four Lunar harmonics

Season	$L_1$	$\lambda_1$	$L_2$	$\lambda_2$	$L_3$	$\lambda_3$	$L_4$	$\lambda_4$
December solstice	0.70	95° 25'	1.21	331° 07'	0.61	350° 39'	0.30	322° 48'
Equinox	0.73	143° 15'	0.98	168° 32'	0.56	127° 55'	0.27	184° 00'
June solstice	0.57	104° 39'	1.08	353° 18'	0.48	118° 27'	0.20	154° 24'

TABLE 2  
Amplitudes and phases of Solar Geomagnetic Tides at Apia (1950-54) for the three seasons (amplitudes in  $\gamma$ )

Season	$S_1$	$\sigma_1$	$S_2$	$\sigma_2$	$S_3$	$\sigma_3$	$S_4$	$\sigma_4$
December solstice	18.1	286° 35'	9.7	107° 17'	4.0	303° 50'	0.7	167° 59'
Equinox	15.7	302° 29'	7.8	115° 34'	2.8	300° 45'	1.0	98° 56'
June solstice	13.9	306° 35'	4.9	140° 18'	1.6	12° 27'	0.2	57° 08'

but less than the first. The fourth is much less than the third.

The second harmonic for each season is represented in the form of the 12-hour harmonic dial (Fig. 1). The projected line stands for December solstice, the cross for the equinox and the open circle for the June solstice.

The amplitude of  $L_2(H)$ , the main component of the lunar geomagnetic tide, is larger in December solstice than in the June solstice. This is to be expected as December is the southern summer. The magnitude of  $L_2(H)$  is not abnormal as we find in Huancayo as Apia is far away from the region of abnormally large amplitudes. Although Apia and Huancayo (Geographic latitude 12° 0S) are on nearly the same geographic latitude, the amplitude of  $L_2(H)$  is very large at Huancayo, but normal at Apia. This implies geomagnetic control of the  $L$  field, for their geomagnetic latitudes are widely different, and the large variation of  $L(H)$  is confined to a narrow strip close to the geomagnetic equator.

The phase of  $L_1(H)$  decreases from summer to winter at Alibag while it increases at Apia, while the phase of  $L_2(H)$  increases by about 20° at both the stations. But the phase of  $L_3(H)$  decreases from summer to winter by about 20° at Apia, and increases by 20° at Alibag. The phase of  $L_4(H)$  decreases at both the places. Thus  $L_1(H)$  and  $L_3(H)$  behave similarly and  $L_2(H)$  and  $L_4(H)$  behave similarly, with regard to the seasonal variation in phase, at Apia and Alibag.

In the equinoctial season the amplitude of  $L_1(H)$  is largest for the year both at Alibag, and Apia; the amplitude of  $L_2(H)$  is intermediate between the summer and winter values. But the behaviour of  $L_3(H)$  and  $L_4(H)$  is different at these two places.  $L_3(H)$  and  $L_4(H)$  at Alibag are the largest values for all the seasons, while at Apia they are intermediate between the summer and winter values. Generally, the seasonal variations of the  $L$  field appear to show contrasting features at Apia and Alibag. These two stations can be regarded as symmetrical along the magnetic equator, in many respects.

TABLE 3  
Amplitude ratio  $S_1(H)/L_2(H)$

Station	December solstice (D)	Equinox	June solstice (J)	Difference (D-J)
Alibag	8.3	15.4	12.1	3.8
Apia	15.1	16.0	12.9	2.2
Huancayo	5.1	8.8	16.5	11.4

#### 4. Discussion of Solar Geomagnetic Tides

The solar geomagnetic tides have been worked out up to four harmonics for each of the three seasons. The amplitudes and phases of these harmonics are given in Table 2.

The solar daily variation at Apia has been represented in Fig. 2 in the form of a diurnal wave, synthesised for the first four harmonics of  $S(H)$ . The prominent harmonic is the first one. The second harmonic is comparable with the first. Unlike the  $L(H)$ ,  $S(H)$  does not show any appreciable seasonal variation either in amplitude or in phase. Apia shows one peculiar characteristic which is not noticeable in any other low latitude station. The maximum amplitude occurs in the December solstice (southern summer) and minimum in the June solstice. But at other stations, viz., Kodaikanal, Alibag, San Juan and Honolulu, the equinoctial amplitudes are the highest for the year. In this regard, Apia shows characteristics of a middle or high latitude station where the summer amplitude is the highest and winter amplitude the lowest. At Apia the phase angles of the first two harmonics are greater in winter than in summer.

As has been mentioned in Sec. 3, in respect of the  $L(H)$ , in the  $S(H)$  also, the amplitude observed is not abnormal although its geographic latitude is  $13^\circ\text{S}$  and Huancayo whose geographic latitude is  $12^\circ\text{S}$  under the influence of electro jet showed abnormally large  $S(H)$  variation. This indicates a geomagnetic control of  $S(H)$ .

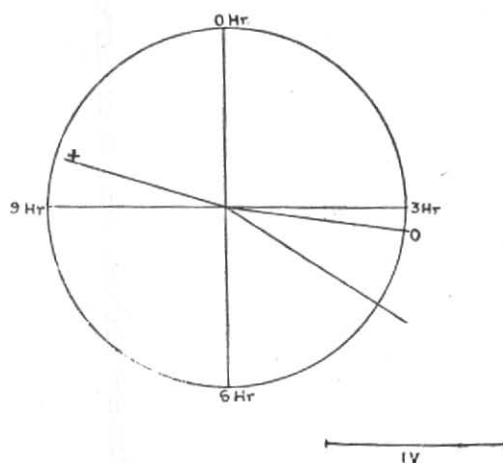


Fig. 1. Harmonic dial for the semidiurnal lunar geomagnetic tides at Apia 1950-54

#### 5. Comparison of $S(H)$ and $L(H)$

The dominant harmonic of  $S(H)$ , viz., the first has been compared with the dominant harmonic in  $L(H)$ , viz., the second. The amplitude ratio  $S_1(H)/L_2(H)$  for Alibag, Huancayo and Apia are given in Table 3.

Alibag and Apia show similar variation, i.e., higher value in summer (which is December in Apia) and lower value in winter. But at Huancayo the higher value is in June; this is due to the abnormally large seasonal variation in  $L_2(H)$ , which is very large in December.

#### 6. Conclusion

The amplitudes of the solar and lunar daily variations are not abnormally large at Apia, although Apia is only one degree further south of Huancayo geographically. This shows that the  $S(H)$  and  $L(H)$  variations are not dependent on geographic latitude, but on geomagnetic latitude. The seasonal variations of the  $L$  field show contrasting features at Alibag and Apia. Apia shows in some respects, the characteristics of middle latitude station.

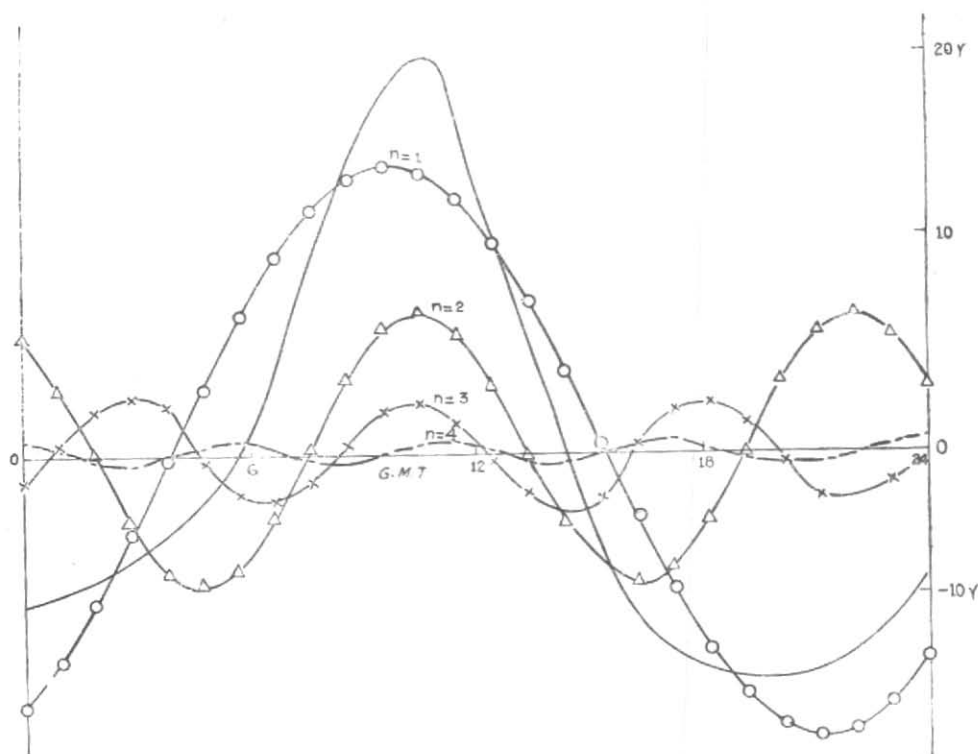


Fig. 2. Solar daily variation at Apia (Thick curve) synthesised from the first four harmonics ( $n=1, 2, 3, 4$ ) for 1950-54

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