Geomagnetic Solar and Lunar Daily Variations at Alibag, India

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Abstract — Geomagnetic solar and lunar daily variations \( S \) and \( L \), at Alibag, India are derived, by the well-known Chapman–Miller method, from the series of homogeneous mean hourly magnetic data of the years 1932 to 1972. The data for all the three elements — declination \( D \) and horizontal and vertical intensities \( H \) and \( Z \) — are analysed, by dividing the data suitably for a study of the seasonal variations, the effect of the changes in the solar and magnetic activities on \( S \) and \( L \), the oceanic dynamo contribution to \( L \), and their interactions with each other. The main results are as follows.

(i) For \( S \) the daily pattern and its seasonal progression conform to the type expected from a northern-hemisphere station. On the other hand, the amplitudes of all the four harmonics of \( L \) systematically have higher values in winter, and in \( D \) and \( Z \) the harmonics show large phase differences between summer and winter. The pattern of \( L \) in winter suggests that the lunar current system consists of a single set of vortices in the summer hemisphere rather than the conventional vortices, one set in each of the hemispheres.

(ii) Solar-cycle modulation on the solar ranges as well as on the amplitudes of the first three harmonics of \( S \) is greater than that expected solely from the increase in E-region conductivity, whereas the corresponding modulation on \( L \) is comparable to that on the E-region conductivity.

(iii) With increasing magnetic activity the first harmonic of \( S \) shows an increase, and the first three harmonics of \( L \) indicate a general decrease, in amplitude.

(iv) Of the variability in \( S \) 96%, but in \( L \) only 32%, is found to be accounted for by the combined effect of the variations in the solar and magnetic activities.

Key words: Solar daily variation; Lunar daily variation; Solar-cycle modulation.

1. Introduction

The Sun and the Moon both exert tidal influences on the Earth. Because of the nearness of the Moon to the Earth, lunar tidal action is about 2.2 times as great as that of the Sun (Jones, 1943). The ionizing wave and particle radiations from the Sun, however, have a profound effect on the Earth's atmosphere. The electric currents that consequently flow in the upper layers of the atmosphere are the primary source of the smooth daily variations and also of some of the irregular or disturbance variations in the geomagnetic field on the Earth's surface. Lunar tidal action on the ionized layers also causes variations in the geomagnetic field, but these are of very small magnitude. The lunar tide is purely gravitational and is essentially lunar-semi-diurnal in its effect on the electrical state of the atmosphere, which is a function of solar time. As the solar and

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lunar days are incommensurable, the geomagnetic lunar daily variation \( L \) is not purely lunar-semi diurnal but contains other harmonics whose phase is dependent, in general, on both the lunar time and the solar time. For a reliable estimate of the very small magnitude of \( L \) the use of data over a long period is necessary, if the much larger solar variation \( S \) and the irregular effects of the magnetic disturbance are to be fairly completely removed. In view of this, a comparatively long and continuous series of homogeneous geomagnetic observations at Alibag has been taken advantage of in a study of the morphology of \( S \) and \( L \) in the low latitudes.

The Alibag magnetic observatory (geographic latitude 18°38′N, longitude 72°52′E; geomagnetic latitude 9°5′N, longitude 143°6′; dip about 24°), established in April 1904, is an Indian equatorial station outside the electrojet belt. Tabulations of the hourly mean values of the field for the three components horizontal and vertical intensities \( H \) and \( Z \), respectively, and the declination \( D \) are available in computer-compatible form from the year 1932. Therefore, the data during the period 1932–1972 are analysed for \( S \) and \( L \) in relation to different parameters, viz., season, relative sunspot number, and magnetic activity, that affect the ionospheric conductivity and air motions. This information would enable one to have a better understanding of the relative importance of the tidal oscillations and atmospheric conductivity. The contribution of the oceanic dynamo, resulting from the tidal movements of the conducting waters of the ocean across the geomagnetic field, has to be taken into account, since Alibag is a coastal station. This contribution would be considerable in \( L \), especially to the second harmonic, but negligible in \( S \) (MALIN, 1970).

Pioneering studies of \( S \) and \( L \) with the use of data from the Colaba magnetic observatory in Bombay (the predecessor of the Alibag observatory) were done by the first two directors of the Colaba observatory, Dr Charles Chambers and Dr N. A. F. Moos, in the last part of the nineteenth century and early years of this century, and were discussed in the light of the then prevailing knowledge of the ionosphere and the tidal and thermal oscillations of the atmosphere. The forms of the curves for the separate lunar phases suggest that one might derive them from the mean curve (a repeated wave) by magnifying that part of it which falls in the hours of daylight. Moos (1910) expressed this idea mathematically. CHAPMAN (1913) modified that expression to the form

\[
L = \sum_{n=1}^{4} l_n \sin (nt - 2\nu + \lambda_n) \tag{1}
\]

where \( l_n \) and \( \lambda_n \) are, respectively, the amplitude and phase angle of the \( n \)th harmonic \((n = 1 \text{ to } 4)\), \( t \) is solar time, and \( \nu \) is lunar age.

2. The data

The data used are the hourly mean values of the three geomagnetic elements \( D \), \( H \), and \( Z \) at Alibag during the period from 1932 to 1972, available in the yearbooks. The