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On the Association of Lunar Daily Variations in *H* at Alibag with the Degree of Magnetic Activity*)

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Summary

The lunar semidiurnal term of the phase law tides in the horizontal intensity at Alibag is found to undergo a systematic decrease in amplitude with increase in magnetic activity. An examination of the results reported earlier for some stations and those of Alibag suggests that there is a general decrease of amplitude with increase in magnetic activity at stations where the lunar time of maximum is around the time of magnetospheric expansion for the lunar tide and an increase in amplitude for stations where the lunar time of maximum is around the time of magnetospheric contraction. In the partial tides, only the phase angle of the second harmonic shows a systematic decrease with increase in magnetic activity.

Zusammenfassung

Das lunare Halbtagsglied der geomagnetischen Horizontalintensität zeigt nach Beobachtungen in Alibag eine systematische Abnahme der Amplitude mit steigender magnetischer Aktivität. Eine Überprüfung der früher für andere Stationen berichteten Ergebnisse und derjenigen von Alibag führt zu der Schlußfolgerung, daß an Stationen, an denen die Mondzeit des Maximums etwa mit der Zeit der magnetosphärischen Expansion, die im Zusammenhang mit der Mondtide steht, eine allgemeine Amplitudenabnahme, dort dagegen, wo die lunare Maximalzeit mit der magnetosphärischen Kontraktion koinzidiert, eine Amplitudenzunahme zu beobachten ist. Bei den Partialtiden zeigt nur der Phasenwinkel der zweiten Harmonischen eine systematische Abnahme mit anwachsender magnetischer Aktivität.

1. Introduction

One of the outstanding problems for future work which the Joint IAGA/IAMAP Committee on Lunar Variations (Transactions of the XVth General Assembly, Moscow, USSR, 1971) pointed out was concerned with lunar variations in the magnetosphere. The index *Ap* of magnetic activity is directly related to solar wind velocity and hence to the intrinsic state of the magnetosphere. In this note, we report the association of lunar diurnal variations with the degree of magnetic activity derived from an analysis of a long series of horizontal intensity (*H*) observations at Alibag, by classifying the days according to the magnitude of *Ap*.

2. Data and analysis

Absolute hourly mean values of *H* at Alibag for the period 1932–1970 are available in machine readable form. The U.T. days with *Ap* in the intervals 0–7, 8–17 and 18–79 represent quiet, moderately disturbed and disturbed groups respectively. Days with even one hourly value missing have been excluded from the analysis. Following

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the procedure of CHAPMAN and MILLER [1], as detailed earlier (RAO [5]), amplitudes and phase angles of the first four harmonics of lunar terms called the lunar phase law tides and their probable errors (p.e.) have been computed for each of three groups. Lunar partial tides were also computed by the numerical procedure as given by WINCH [7]. The computational technique and the definition of the terms of lunar partial tides are detailed in RAO and SASTRI [6]. The results of both phase law and partial tide terms together with the number of days included in each group are given in Table 1. LEATON

Table 1. Lunar harmonic components of H at Alibag for three groups of magnetic activity (amplitude and p.e. in units of 0.01 γ)

Tides	n	Quiet $Ap = 0-7$ 5508 days			Moderately disturbed $Ap = 8-17$ 5140 days			Disturbed $Ap = 18-79$ 3263 days		
		Amplitude	±p.e.	Phase [degrees]	Amplitude	±p.e.	Phase [degrees]	Amplitude	±p.e.	Phase [degrees]
Phase law	1	81	21	350	47	26	9	97	42	311
	2	92	11	176	69	12	176	54	24	136
	3	32	05	2	27	09	332	45	11	22
	4	09	04	186	02	06	290	14	10	257
Partial	1	14	16	192	30	24	111	23	28	123
	2	21	08	283	20	12	237	17	21	149
	3	05	06	279	09	11	31	12	12	91
	4	03	05	32	02	07	291	13	12	179

et al. [3], while studying the association of lunar tide with the degree of magnetic activity, have given the ratio 3:2:1 for the number of disturbed, moderately disturbed and quiet days respectively, to approximately equalize the effect of transient variations on the significance of the results, by producing similar probable errors for each of the magnetic activity divisions. Accordingly, lunar phase law and partial tides were recomputed, grouping the days in the Ap intervals 18–50, 10–13 and 2–3 for disturb-

Table 2. Lunar harmonic components of H at Alibag for three groups of magnetic activity. Weightages are given to the number of days in each group (amplitudes and p.e. in units of 0.01 γ)

Tides	n	Quiet $Ap = 2-3$ 1295 days			Moderately disturbed $Ap = 10-13$ 2221 days			Disturbed $Ap = 18-50$ 2970 days		
		Amplitude	±p.e.	Phase [degrees]	Amplitude	±p.e.	Phase [degrees]	Amplitude	±p.e.	Phase [degrees]
Phase law	1	125	28	351	68	42	08	106	44	310
	2	85	16	183	59	21	184	62	28	143
	3	33	08	346	30	13	310	39	11	16
	4	17	05	200	11	06	167	20	11	259
Partial	1	48	27	222	28	38	162	22	25	92
	2	20	13	239	08	21	202	18	22	170
	3	12	09	49	24	17	55	14	12	49
	4	05	07	38	05	09	292	15	13	165

ed, moderately disturbed and quiet groups respectively, which approximately satisfied the ratio 5:4:2. Results of this analysis are given in Table 2.

Any harmonic in Tables 1 and 2 can be considered as significant at five per cent level if its magnitude is 2.08 times the corresponding p.e. This factor is derived from the procedure used for calculating the p.e. Only the first and fourth harmonics of the moderately disturbed group and the fourth harmonic in the disturbed group of phase law tides in Tables 1 and 2 fail to satisfy this test of significance. As expected, the magnitudes of the p.e. are very much higher in the quiet and moderately disturbed groups in Table 2, where weightages are given for the number of days in each group. However, there is little change in the magnitude of p.e. in the disturbed group between the values computed with and without weightages respectively. Except for the second harmonic in the quiet interval, given in Table 1, none of the harmonics of partial tides is significantly determined.

3. Discussion

In the lunar phase law tides, the most important harmonic component, viz. the semidiurnal component, shows a general decrease of amplitude with increase in magnetic activity. In fact the decrease of amplitude is systematic in the results presented in Table 1. Though the magnitudes of the first harmonic are comparable with those of the second harmonic, there is no systematic variation of the amplitude of the first harmonic with the degree of magnetic activity.

LEATON et al. [3] selected the international character figure C and coded each day of any particular month into three categories — *0* for five I.Q. days, *2* for the fifteen most disturbed days and *1* for the remaining days of the month — in their analysis of data from Greenwich and Abinger. They showed that there was a marked tendency for the lunar semidiurnal component in H and D to decrease with increasing magnetic activity. WINCH [7] divided the geomagnetic data of Toolangi according to magnetic activity by calculating the daily range of each daily sequence of values about the corresponding monthly mean sequence. The daily ranges were then placed in order of magnitude, and ranges were selected which divided the data into three equal parts after allowing for missing days. It can be seen from the results given in his Table 6 that there is a systematic increase of the lunar semidiurnal component of H with the increase in magnetic activity. GREEN and MALIN [2], following the criterion for grouping the days according to magnetic activity used by LEATON et al. [3], have also shown, for Watheroo, an increase in the magnitudes of the lunar harmonics of all the elements with increase in magnetic activity. Thus, both the selection criteria for the magnetic activity index and the principal results regarding the general dependence of lunar phase law variations on magnetic activity are differing. The association between amplitude and magnetic activity reported in this communication is in agreement with the results for Greenwich and Abinger, given by LEATON et al. [3]. However, the types of trends in the change of phase with increasing magnetic activity observed by them are not immediately discernible in the variations of the phase angle at Alibag.

MAEDA [4] reported that the background plasma in the magnetosphere above about 150 km could oscillate by the electromagnetic force, where the electric field seems to be transferred from the dynamo region along the geomagnetic field lines. These oscillations, known as hydromagnetic tides in the magnetosphere, were obtained on the basis of the electrostatic fields in the dynamo region as deduced from solar and lunar geomagnetic variations. He found that apart from the expansion during the day and contraction during the night for the solar tides, the magnetosphere expands around 00 and 12 hours and contracts around 06 and 18 hours lunar time for the lunar tides. An average lunar semidiurnal component at each station from three magnetic activity groups is obtained by vectorial addition. The times of first maxima for this average component at Greenwich, Abinger, Alibag, Toolangi and Watheroo are respectively 1.9, 1.5, 9.4, 4.2 and 4.2 hours lunar time. Thus the times of maxima at Greenwich, Abinger and Alibag are near the time of expansion of the magnetosphere for the lunar tides, whereas the times of maxima at Toolangi and Watheroo are close to the time of contraction of the magnetosphere. It, therefore, appears that for stations where the lunar time of maximum is around the time of magnetospheric expansion for the lunar tides, there is a general decrease of amplitude with increase in magnetic activity. For those stations where the lunar time of maximum is around the time of magnetospheric contraction an increase of amplitude with increase in magnetic activity is observed.

RAO and SASTRI [6] have shown that in the Indian region the second harmonic of the partial tide in H is generally prominent. As seen from Table 1, this is found to be so only during the quiet interval. The phase angle of this harmonic shows a systematic decrease with increasing magnetic activity. For partial tides at Toolangi, WINCH [7] found that only the phase angle showed a dependence on magnetic activity. However, this dependence is seen only for the phase angle of the second harmonic at Alibag.

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