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On the amplitudes of diurnal and semi-diurnal components of geomagnetic variation

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ABSTRACT. Study of the amplitudes of the diurnal and semi-diurnal components of the geomagnetic daily variation in H shows that the solar cycle variation in the two components are different and the relative increase from winter to equinox of the amplitude in semi-diurnal component is more than that for the diurnal component.

1. Introduction

Many investigations have been carried out about the diurnal and semi-diurnal components of the daily variations of the geomagnetic field and the winds in ionosphere responsible for these components. The winds that produce the daily magnetic variation by dynamo action arise both from solar heating of the ionospheric air and from gravitational tides. The relative contributions of these winds to the diurnal and semi-diurnal components of the magnetic variation are, however, not clearly known. Rishbeth and Garriot (1964) pointed that the dominant period of the daily magnetic variation was 24 hours, since E-region electron density changed by a factor of 30 or more between night and day. From a study of the amplitudes of the first and second harmonics of the yearly mean diurnal $Sq(H)$ at Alibag, Yacob and Prabhavalkar (1965) showed that the amplitudes of both harmonics had good correspondence with solar activity. Using monthly mean $Sq(H)$ for Alibag, Yacob and Radhakrishna Rao (1966) computed the annual variation of the amplitudes of the first two harmonics and the lines of regression between sunspot number and amplitudes. They showed that the annual variation of C_1 and C_2 were similar. Gupta (1967) studied the contribution to the diurnal and semi-diurnal components of magnetic variation by solar radiation input and gravitational tides, by computing coherence and partial coherence functions for various time series and concluded that at the diurnal frequency solar radiation accounted for 99% of the variation and at the semi-diurnal frequency, the contribution from solar ionising radiation was 90%, and the balance 10% from gravitational tides. In this communication, the amplitudes of the diurnal and semi-diurnal components of the geomagnetic daily variations in H at four equatorial stations, Trivandrum (dip Lat. 0°·5 S), Kodaikanal (dip Lat. 1°·5 N), Annamalainagar (dip Lat. 2°·8 N) in the vicinity of the dip equator and Alibag (dip Lat. 12°·5 N) have been computed for intervals representative of equinoctial and winter conditions over a period of about a solar cycle. The variations in amplitudes of these two components of the diurnal variation of the magnetic field, with season and solar activity are discussed.

2. Data and analysis

Hourly values of the horizontal intensity for the pairs of months March-April and November-December were subjected to spectral analysis following the method outlined by Blackman and Tukey (1959). Each series consisted of 1464 hourly values. With a maximum lag of 120, the computations provided spectrums with a very high degree of reliability (degrees of freedom being about 24). The computations were carried out for the intervals 1958 to 1969 except for Kodaikanal where these were restricted to periods upto 1967 and 1966 respectively, for lack of data. From the power densities, the amplitudes corresponding to the period of 24 hours and 12 hours were calculated from the relationship : Amplitude$=2\,(\text{Power})^{\frac{1}{2}}$. The amplitudes for each year and the corresponding bi-monthly mean sunspot number are given in Table 1.

TABLE 1

Amplitudes of diurnal and semi-diurnal components of geomagnetic daily variation in '*H*'

Year	March-April									November-December									
	SSN	24-hour				12-hour				SSN	24-hour				12-hour			
		TRV γ	KOD γ	ANR γ	ALB γ	TRV γ	KOD γ	ANR γ	ALB γ		TRV γ	KOD γ	ANR γ	ALB γ	TRV γ	KOD γ	ANR γ	ALB γ
1958	193·3	73·18	68·44	58·04	36·78	34·88	31·88	26·36	15·80	170·0	53·02	48·84	41·02	30·72	22·26	19·80	16·24	10·82
1959	174·5	69·92	66·16	56·56	36·78	34·68	31·12	25·69	14·88	124·5	48·58	46·06	39·52	28·84	23·54	20·50	17·42	11·74
1960	112·1	59·44	59·30	47·56	32·72	29·12	27·00	21·26	12·60	87·6	38·22	35·26	29·74	21·94	18·48	15·88	12.48	8.84
1961	57·2	44·90	42·68	35·66	24·16	26·70	24·90	20·00	11·90	36·3	35·16	34·24	29·16	21·32	16·66	15·24	12·32	7·50
1962	46·0	42·42	40·10	33·64	21·54	24·50	22·54	18·58	9·90	25·1	27·68	26·94	22·08	16·88	14·60	13·72	11·20	8·16
1963	23·0	36·12	34·46	28·14	18·12	22·80	21·08	16·74	9·12	19·1	28·78	27·06	22·42	16·00	14·50	12·80	10·14	6·28
1964	13·0	37·14	35·56	28·80	16·88	26·08	24·34	19·22	9·46	11·3	26·08	24·90	20·78	14·46	14·18	12·96	10·42	6·48
1965	9·1	35·94	34·36	28·22	17·02	22·36	21·00	16·62	7·48	16·3	25·86	25·30	20·68	15·56	14·44	13·12	10·68	6·96
1966	36·0	41·28	39·80	32·12	20·50	25·98	23·78	18·84	9·86	63·8	30·22	29·02	24·04	17·24	12·86	12·12	9·72	7·06
1967	90·7	55·14	52·42	42·73	28·44	30·46	27·34	22·89	13·26	110·3	35·86	—	28·64	19·34	17·84	—	13·55	8·74
1968	86·7	49·96	—	39·20	25·06	27·50	—	20·60	12·62	97·9	37·20	—	28·12	17·66	20·84	—	14·30	8·52
1969	121·3	55·10	—	42·38	26·30	32·62	—	24·42	14·34	95·7	37·58	—	28·28	17·56	19·14	—	13·86	7·58

TABLE 2

Equations of lines of regression

Stations	March-April		November-December	
	24-hour	12-hour	24-hour	12-hour
Trivandrum	$Y=\cdot 206X+33\cdot 57$	$Y=\cdot 066X+22\cdot 87$	$Y=\cdot 158X+24\cdot 23$	$Y=\cdot 059X+13\cdot 23$
Kodaikanal	$Y=\cdot 198X+32\cdot 47$	$Y=\cdot 055X+21\cdot 39$	$Y=\cdot 153X+23\cdot 68$	$Y=\cdot 049X+12\cdot 15$
Annamalainagar	$Y=\cdot 168X+25\cdot 98$	$Y=\cdot 051X+16\cdot 85$	$Y=\cdot 121X+19\cdot 34$	$Y=\cdot 042X+9\cdot 71$
Alibag	$Y=\cdot 112X+16\cdot 44$	$Y=\cdot 040X+8\cdot 59$	$Y=\cdot 086X+14\cdot 09$	$Y=\cdot 029X+6\cdot 27$

Y=Amplitude in gammas X=Sunspot number

TABLE 3

Ratio of amplitudes : Equinox/Winter of diurnal and semi-diurnal components of daily magnetic variation in '*H*'

Year	24-hour				12-hour			
	TRV	KOD	ANR	ALB	TRV	KOD	ANR	ALB
1958	1·380	1·401	1·415	1·197	1·567	1·610	1·623	1·460
1959	1·439	1·436	1·431	1·275	1·473	1·518	1·475	1·267
1960	1·555	1·682	1·599	1·535	1·576	1·700	1·704	1·425
1961	1·277	1·246	1·223	1·133	1·603	1·634	1·623	1·587
1962	1·533	1·488	1·524	1·276	1·678	1·643	1·659	1·213
1963	1·255	1·273	1·255	1·133	1·799	1·647	1·651	1·452
1964	1·424	1·428	1·386	1·167	1·839	1·878	1·845	1·460
1965	1·390	1·358	1·365	1·094	1·548	1·601	1·556	1·075
1966	1·366	1·371	1·336	1·189	2·020	1·962	1·938	1·397
1967	1·538	..	1·492	1·471	1·707	..	1·689	1·518
1968	1·343	..	1·507	1·489	1·320	..	1·441	1·683
1969	1·466	..	1·499	1·497	1·704	..	1·762	1·892

TABLE 4

Correlation coefficients between sunspot number and amplitudes of 24-hour and 12-hour components of magnetic variation

Stations	March-April		November-December	
	24-hour	12-hour	24-hour	12-hour
Trivandrum	·988 (97·7)	·946 (89·5)	·927 (85·9)	·853 (72·8)
Kodaikanal	·985 (97·0)	·952 (90·6)	·951 (90·4)	·876 (76·7)
Annamalainagar	·985 (97·0)	·947 (89·7)	·901 (81·2)	·860 (74·0)
Alibag	·963 (92·7)	·950 (90·3)	·840 (70·6)	·870 (75·7)

3. Results and discussion

The familiar feature of the equatorial enhancement of the amplitudes in the diurnal and semi-diurnal components of the variation is noticeable in all the years with Trivandrum closest to the dip equator showing maximum amplitude. The lines of regression between sunspot number and amplitudes of both the components are given in Table 2. For Alibag, the lines are in good agreement with those given for C_1 & R and C_2 & R by Yacob and Rao (1966). This is to be only expected since the dominant part of 24-hour and 12-hour components of the daily variation is only *Sq* and the amplitudes of the disturbance daily variation at these frequencies are very small and hence contribute very little to the total daily variation. It may be seen that the variation of the amplitude with sunspot number is maximum for equinox at station closest to the dip equator and that the variations in the diurnal component are considerably greater than those in the semi-diurnal components as indicated by the 'slopes' of the regression lines. From Table 1, it may be seen that while both the diurnal and semi-diurnal components show decrease in amplitude with decreasing solar activity with maximum in 1958 and minimum in 1964 or 1965, the variation for the semi-diurnal component is small when sunspot number is less than about 60. Again for Alibag, these results are in general agreement with the Figs. 1 and 2 showing variations of C_1, C_2 and R with years, of Yacob and Prabhavalkar (1965). In their study of the solar-cycle dependence of winds in the lower ionosphere from continuous ionospheric drift measurements at low frequencies, Sprenger and Schmider (1969) found that the 12-hourly periodic component decreased in speed with increasing solar activity from 30 or 20 m/sec at solar minimum to below 10 m/sec at solar maximum. It may, hence, be inferred that during periods of low solar activity, as indicated by sunspot number below about 60, the decrease in the amplitude of the 12-hour component of the daily magnetic variation with decreasing solar activity is offset by the probable increase in the amplitude due to the increased velocity of the semi-diurnal winds in the ionosphere with decreasing activity. However, during periods of high solar activity, the variations in amplitude due to variation in the ultra-violet radiation from sun will dominate and the semi-diurnal winds in the ionosphere will contribute little due to its reduced velocity of 10 m/sec.

In Table 3 are given the ratios of the amplitudes in equinox to the amplitudes in winter of both the diurnal and semi-diurnal components. It is seen that, in general for both the components, ratios for Alibag are less than those for the stations in the electrojet belt and that the ratios for the jet stations are comparable. This suggests that the relative increase in amplitude from winter to equinox is higher for the stations in the vicinity of the dip equator as compared to similar increase at a station away from the jet effect. At each station, the ratios for the 12-hour component are higher than the ratios for the 24-hour component suggesting different variations in amplitude of the two components with season. Endo (1957) had also indicated that the seasonal variations in the diurnal and semi-diurnal components of *Sq* were different. Yacob and Rao (1966), however, showed that the seasonal variation of the first and second harmonics of $Sq(H)$ at Alibag were similar but the amplitudes for the annual variations of the two were strikingly different. From the higher ratios for 12-hour component at all the stations noticed here, it may also be inferred that the relative increase in amplitude from winter to equinox is greater for the semi-diurnal component as compared to the diurnal component.

To test the solar control of the amplitudes of both components, correlation coefficients between bi-monthly mean sunspot number and the amplitudes were computed. These are shown in Table 4. The percentage of variation in amplitudes accounted for by the variation in sunspot number, as calculated from $(C.C.)^2 \times 100$, are given in brackets. It may be noted that for equinox, the C.Cs are nearly unity for the diurnal component while it is slightly lower for the semi-diurnal component. The C.Cs are correspondingly lower for winter. In equinox, above 95% of the variation in the diurnal amplitude and about 90% of the variation in the semi-diurnal amplitude is accounted for by the variation in solar activity and consequent variation in ultraviolet radiation. The percentages are relatively lower in winter. For equinox, these percentages for variations above the steady level (corresponding to zero sunspot number) are nearly the same as those obtained by Gupta (1967) for the entire geomagnetic daily variation.

4. Conclusion

1. The relative increase from winter to equinox, in the amplitudes of the two components — diurnal and semi-diurnal — of geomagnetic daily variation are different. The increase for the semi-diurnal component is greater than the increase for the diurnal component. Also, the relative increase at stations within the electrojet belt are greater as compared to a station away from the jet effect.

2. The solar cycle variation in the amplitudes of the two components are different. The semi-diurnal component varies little with solar activity when the activity is moderate or low.

3. The correlation coefficients between sunspot number and amplitudes of the two components in equinox and winter are highly significant and suggest strong linear relationship between solar activity and amplitudes. For equinox, the percentage variation in amplitude, above the steady level, accounted for by the variation in solar activity is nearly the same as obtained for the total geomagnetic daily variation by Gupta (1967).

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