Geomagnetic Solar Quiet Day variation S_q according to LT from the night time datum at Indian stations during 1958

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ABSTRACT. The Sq variation is derived for Alibag, Annamalainagar and Trivandrum for 1958 from retabulated hourly values of H-field according to LT (IST) for the five International Quiet Dates nearest to the local days, from the daily mean as well as from the night time level. Non-cyclic change is calculated for the same according to LT. A Fourier analysis of the S_q derived in the above manner, is performed and the results are compared with the data published in the Bombay Volumes where S_q and non-cyclic change is derived according to GMT. It is observed that there is considerable difference (of the order of 0 to 10γ) in the two estimates of the non-cyclic change, but a small difference (of the order of 0 to 2γ) in the amplitudes of the harmonic coefficients of the S_q derived in the two ways. It is concluded that S_q should preferably be derived from the local time and night time datum.

1. Introduction

According to Chapman and Bartels (1961) the Solar Quiet Day variations, S_q, can in general be derived from the five most quiet days of the month. Some of the workers, however, derive S_q from more than five quiet days (Matsushita and Maeda 1965). But most of the workers follow Chapman and Bartels for deriving S_q from the five International Quiet Days during the month. Many of the observatories publish their hourly magnetic values according to Greenwich Mean Time (GMT or UT) and derive S_q according to GMT, while some other observatories publish hourly values and derive S_q according to the Local Time (LT). Price and Wilkins (1963) in their detailed study of the polar year data have discussed S_q derived according to UT and LT. Sugiura and Chapman (1960) have given an idealized definition of S_q as "the daily magnetic variation characteristic of days when the ionosphere is everywhere ionized only by solar ultra violet radiation". It follows from this that S_q should be derived according to the LT. The geomagnetic data published by Colaba (Bombay) for the IGY period and after for Alibag, Trivandrum and Annamalainagar and for earlier period only for Alibag is according to GMT and S_q is also derived according to GMT. In the present note S_q is derived according to LT (IST) for the above three observatories for IGY (1958) and the results are compared with those given in Colaba Magnetic Volumes according to GMT for IGY. Non-cyclic change and choice of appropriate datum for the S_q are also discussed.

The usual procedure for deriving S_q consists of obtaining monthly means of hourly values for the five International Quiet Days of the month, correcting them for the non-cyclic change and then obtaining the hourly departures of these corrected values from a fixed datum.

2. Non-cyclic change

The non-cyclic change is the difference in the values at two epochs differing by 24 hours and is based on the assumption that the change takes place linearly throughout the day. Price and Wilkins (1963) suggested that the non-cyclic change arises due to the following reasons—

(*i*) A gradual change due to smooth recovery of the field from the effects of magnetic storms,

(*ii*) Short period disturbances affecting the field at the two epochs chosen for measuring the differences, and

(*iii*) Changes of amplitudes or form of the daily variation from one day to the next.

The non-cyclic change is usually taken to be the differences of the values occurring at two epochs coinciding with or close to successive midnights. Price and Wilkins (1963) have shown that the difference between the universal day and the local day for a particular observatory affects the problem of estimating the non-cyclic change. The two estimates differ considerably for observatories which lie more than about 90° from Greenwich meridian. This is because the epochs used for calculating the non-cyclic change than fall in the day light hours and, therefore, the effect of the day-to-day variability of S_q becomes important. The two estimates of non-cyclic change, one from the GMT midnight and other from the local midnight for Alibag, Trivandrum and Annamalainagar are worked out for H-field for 1958 and are given in Table 1.

3. Datum for the S_q

The S_q variation is generally reckoned from the daily mean of each element as basis (Chapman and Bartels 1961). Schimdt has remarked that this is only a convenient but not an essential basis. Price and Wilkins (1963) in their study for the polar year data of 1932-33 have shown that when the field was measured from the daily mean, often at a given epoch of universal time, values round the latitude circles were not zero as they should be. But these non-zero values were greater than that could be reasonably attributed to errors in the interpolation and were reduced when the datum line was changed. Chapman and Bartels (1961) have pointed out that the daily variation curves for Huancayo suggest that the daily change from night value may alter in magnitude from day-to-day while preserving its general character and that the night value remains approximately constant throughout these changes. Also, the daily mean changes considerably from day-to-day and month-to-month. Price and Wilkins (1963) suggested the use of night value as the datum in view of the following considerations —

(*i*) The ionization in the ionosphere is known to decay rapidly after sunset. Hence the ionospheric current system at night may be expected to be very much smaller than that in day-light hours. The electron density in the ionospheric E-layer at night has recently been observed for example, Bourdeau (1963) and is only about one fiftieth of the noon value. If the overhead electric current responsible for S_q variation flows in the E-layer, the current at night should be almost zero because of very small electron density, hence very low electric conductivity.

(*ii*) The changes of the field components during the night are much smaller than during the day and in some cases depending on the component and the season are approximately zero.

(*iii*) The mean value of the day is more affected by the day-to-day variability of S_q and disturbances than is the night value.

According to Matsushita and Maeda (1965), Ashour and Price (reference is not given) in a paper entitled 'Night time earth currents associated with the daily magnetic variations' recently suggested that the overhead electric current for the S_q variation during the day-time may induce an electric current within the earth not only in the day-light hemisphere but also in the night hemisphere. Their result shows that the intensity of the total (overhead and induced) currents at night is about one tenth of the day-time value. According to Matsushita and Maeda if it is so, the night value of the S_q variation should not be taken as a datum line. But the present author feels that this is not much unfavourable as against the merit of night time datum in comparison to the daily mean.

Choice of night time datum — The method of selecting the night time datum also needs some consideration. The following points are mentioned in this connection —

(*i*) The local midnight value — This may not be reliable because of the disturbance effects.

(*ii*) The value, if any, at which the component is approximately constant for several hours. This would seem to be the best but it is not always available.

(*iii*) If there is no such constant value during the night, the mean over several hours may be tried to see if it answers better.

Chapman and Raja Rao (1965) suggested a mean of six-hourly values (0^h, 1^h, 2^h and 21^h, 22^h, 23^h LT) as the datum. Price and Wilkins (1963) have suggested a mean of 21^h to 3^h or 20^h to 4^h to be suitable but they have cautioned for the longer interval as it may introduce error due to noticeable post-sunset and pre-dawn changes. In the present work the night-time datum as suggested by Chapman and Raja Rao is followed.

4. Method

The Colaba magnetic data (as in published volumes) represent the mean hourly values centred at Greenwich Mean Time. For the present analysis the whole data are retabulated from the volumes according to local time, *i.e.*, from 18 GMT of the previous day to 18 GMT of the actual International Quiet Day corresponding to 0^h to the 0^h of the LT. The mean 25-hourly values for such five International Quiet Dates nearest to the local days are thus obtained. They are corrected for allowance for mean and the non-cyclic change which is obtained from the terminal and initial values. The mean hourly values are corrected for the non-cyclic change in the usual manner, assuming that it is distributed linearly throughout the day. The mean of six-hourly values $18^h + 19^h + 20^h$ and $16^h + 17^h + 18^h$ GMT corresponding to 0^h, 1^h, 2^h and 21^h, 22^h and 23^h LT gives the night time datum. The variation is reckoned from this datum. Also the variation is obtained from the daily mean of the above set of values for comparison. Care has been taken to neglect a day's consideration where it is preceded by a disturbed day or has missing values for more than two hours. Although at times this may reduce the number of quiet days by one or two in extreme cases, the risk of including disturbance effect is minimised. These two sets of S_q s according to LT are compared with that published in Colaba Magnetic Volumes

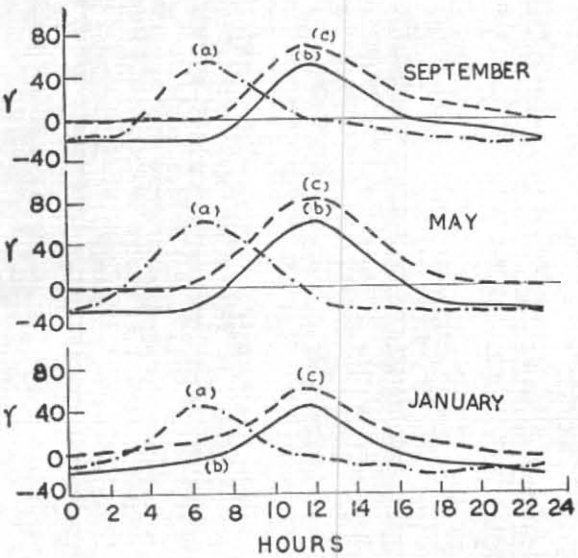

Fig. 1(a). Alibag

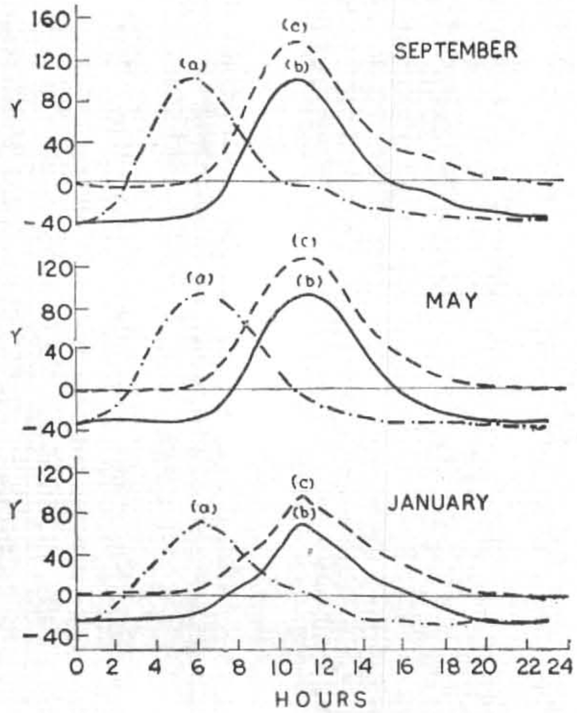

Fig. 1(b). Annamalainagar

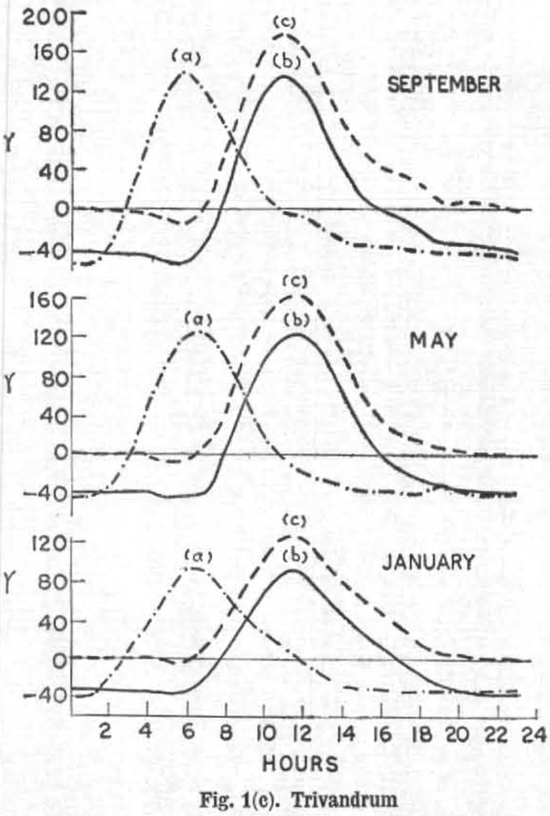

Fig. 1(c). Trivandrum

Figs. 1(a)-1(c). S_q in 1958 derived in the three ways
(a) according to GMT from the daily mean,
(b) according to LT from the daily mean,
(c) according to LT from night time datum

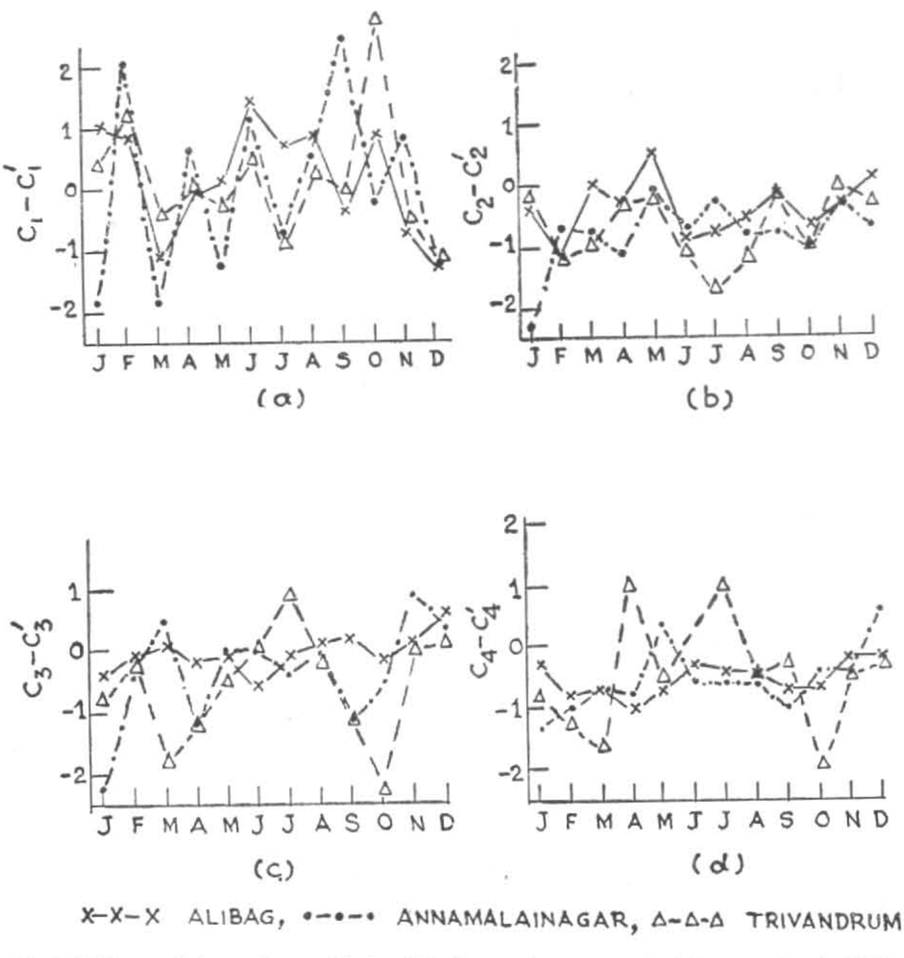

Fig. 2. Difference between the amplitudes of the harmonic components of S_q according to GMT and according to LT at three stations. (a) First component, (b) Second component (c) Third component, (d) Fourth component

TABLE 1

Estimates of non-cycle change in H (γ) from GMT and LT midnights

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						ALIBAG						
GMT	6·2	11·7	11·3	8·9	8·1	13·8	4·2	5·0	6·1	5·1	9·4	13·9
LT	10·0	17·8	7·8	7·4	3·4	19·6	7·4	8·2	5·8	11·8	7·6	9·6
						ANNAMALAINAGAR						
GMT	6·5	10·9	9·6	0·0	7·1	12·2	3·1	5·9	5·2	1·0	14·6	12·5
LT	10·0	18·0	7·0	4·7	3·4	18·6	3·7	9·8	14·8	7·8	11·0	10·2
						TRIVANDRUM						
GMT	5·7	11·1	8·7	13·3	8·0	13·7	2·9	6·1	5·6	4·1	9·6	15·1
LT	9·4	19·8	5·0	10·9	5·4	20·0	6·0	9·2	6·4	11·6	8·0	12·2

(according to GMT). To show the comparative forms of the above three types of S_q, the S_q values are graphed in Figs. 1(a), 1(b), 1(c) for Alibag, Annamalainagar and Trivandrum respectively.

Fourier analysis of the S_q variation — The mean hourly inequalities of horizontal force for the five International Quiet Dates nearest to the local days are subjected to Fourier analysis monthwise and the amplitudes and phase angles of the first four harmonic components are calculated. The results are compared with those calculated from the GMT hours as published in Bombay Magnetic Volumes and differences for the first four harmonics are graphed in Fig. 2.

5. Discussions and remarks

It is seen from Table 1 that the estimates of non-cyclic change from local midnight hours are quite different than that derived from the GMT midnights for all the three stations. It is also seen that the difference is more for Trivandrum (1 to 9 γ) and Annamalainagar (1 to 10 γ) and comparatively less for Alibag (0 to 7 γ). The difference is more for the D and J seasons than for E seasons for all the three stations. This observation is also in confirmation with the observation of Price and Wilkins (1963) for Watheroo for the polar year 1932-33.

Fig. 1 shows that there is a phase shift in maxima for S_q from GMT and LT estimates (curves a and b). The order of difference is about 5 hours which is also the difference between the LT (IST) and GMT. The other significant difference between the curves a and b is in their forms as referred from the position of respective maxima. The curve b is more or less symmetrical with respect to its maximum on its either side while the curve a is bit asymmetric with respect to its maximum. The asymmetry arises not only because the former is in LT and the latter in GMT but also mainly because there amounts to be some ten hours of phase difference altogether for each International Quiet Day and the day in LT. In the case of curve c which represents S_q derived according to LT from local night level as defined earlier, the only difference seen is because of the change of the datum. The forms of b and c remain the same.

It can be seen from Fig. 2 that there is some small difference in the amplitudes of the Fourier components of the S_q derived according to LT and GMT. The order of difference is about 0 to 2 γ. This difference arises because of the difference in the two estimates of the non-cyclic change to which the S_q is corrected before obtaining variation.

6. Conclusion

In conclusion it is emphasised that although for stations which are not much away from Greenwich Meridian the difference between the two estimates of S^q, one according to LT and another according to GMT, is not very significant and may to some approximation be derived simply by making allowance for the phase shift between the GMT time and LT but certainly for stations farther away from Greenwich, large differences would arise between the two estimates because of the solar ultraviolet radiations causing S_q coming into the picture. For the three Indian stations Alibag, Annamalainagar and Trivandrum the difference in GMT and LT is 5 to 5½ hours and so a definite change is seen in the above analysis. Thus, to be on the safe side, the S_q variation should be derived from the International Quiet Days nearest to the local days according to LT and also from the night level as the datum, so as to get a fairly good approximation of S_q. Also, if the S_q for individual hours are required it is by all means advised to derive it according to LT from the night datum.

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