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On abnormal quiet-day variation in the low latitudes

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ABSTRACT. Abnormality in the phase of $Sq(H)$ has been studied from extensive data of Alibag. The occurrence frequency of abnormal quiet days (AQDs) shows a semi-annual variation with maxima in winter and summer solstices and minima in equinoxes; it has negative correlation with solar activity. North-south asymmetry and day-to-day changes in the Sq current system are suggested as probable causes of magnetic variation on abnormal quiet days.

1. Introduction

Visual inspection of magnetograms shows considerable changes in amplitude and time of maximum in the diurnal variation of geomagnetic elements from one day to another and this is so even on quiet days. This day-to-day variability has been attributed to variations of the current system responsible for the S_q variation. From a consideration of the nature of diurnal variation of northward directed intensity, X, at stations in the latitude range 30°-40°, Hasegawa (1936) concluded that the focus of the S_q current system may move by as much as 15° north or south from one day to another. Using IGY data Hasegawa (1960) concluded that day-to-day changes in the S_q focus are probably due to dynamic causes rather than to changes in the distribution of ionization and conductivity.

According to Afanas'yeva (1961) corpuscular injection from outside the atmosphere could cause the day-to-day variability, and, according to Mayaud (1965), the variability could be attributed to the Cp current system in the polar region. Brown and Williams (1969) studied the day-to-day variability in the phase of diurnal variation of H at Abinger (Geog. coordinates : 51° 11′ N, 0° 23′ W) and three other stations and showed that the variability arises either from solar influences on atmospheric dynamics or from an extra-terrestrial cause. They also found a marked solar control of the day-to-day variability in the phase of S_q (H) and observed that the frequency of abnormal quiet day showed seasonal and solar cycle variations. They suggested that further work on the geographical extent of abnormality in the phase may help in providing a better clue to its origin. Of the four stations studied by them, three were on the poleward side of the S_q focus in the northern hemisphere and the fourth on the equator side in the southern hemisphere. As Alibag (Geog. coordinates: 18° 38′ N, 72° 52′ E) is in the northern hemisphere on the equatorial side of the S_q focus and has an extensive series of uninterrupted data, an attempt is made here to study the day-to-day variability in the phase of S_q (H) following the method of Brown and Williams (1969).

2. Data and analysis

The times of instantaneous maximum of horizontal force on international quiet days between 1932 and 1969 were grouped according to their hour of occurrence. On most of the days, time of maximum was in the interval 0500-0800 hr UT, with highest frequency restricted to 0600-0700 hr UT (51·9 per cent of the total I.Q. days considered). There were, however, extreme variations for which maximum was outside this time interval. Following Brown and Williams, these days have been termed 'Abnormal Quiet Days' (AQDs). The analysis in the present communication is confined to these days. Out of the total of 2,280 international quiet days during the period, 158 days representing 6·9 per cent days were AQDs.

3. Annual variation

Fig. 1, where the percentage of AQDs is plotted as a function of the month, shows that maximum AQDs occurred in the month of January with 13·8 per cent of I.Q. days being abnormal. This proportion reduced to less than 3 per cent in March-April and October. The percentage of AQDs in July-August is only slightly smaller compared to the winter months. From Fig. 1 it is also seen that the percentage occurrence of AQDs is predominantly semi-annual with maxima in the winter and summer, and minima in the equinoxes, with a small annual component. Data for Trivandrum (Geog. coordinates : 8° 29′ N, 76° 57 ′E) near the magnetic equator for the period 1959-1968 were similarly

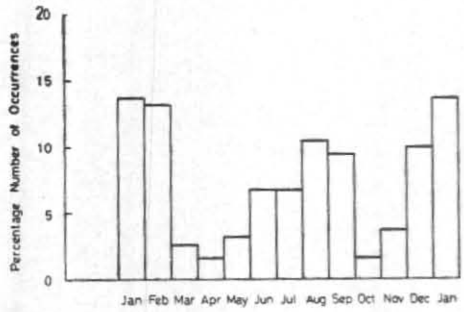

Fig. 1

Percentage number of occurrences of abnormal phase of $S_q(H)$ for each month at Alibag

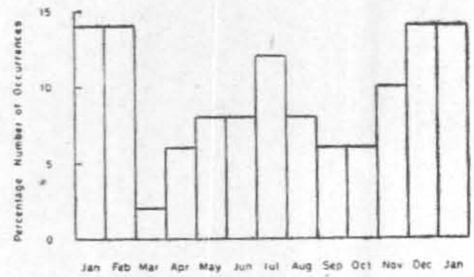

Fig. 2

Percentage number of occurrences of abnormal phase $S_q(H)$ for each month at Trivandrum

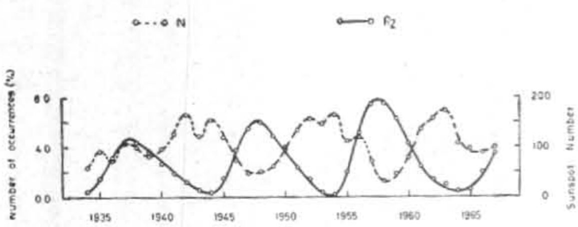

Fig. 3

Variation of number of occurrences (N) of abnormal phase of S_q (H) and annual mean sunspot number(R_z) with year

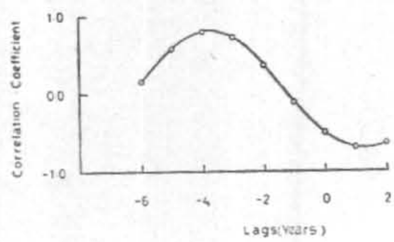

Fig. 4

Lagged correlation coefficient between annual number AQDs and sunspot number (R_z)

analysed to understand the morphology of these AQDs. Fig. 2 shows the percentage frequency of AQDs in different months. This again clearly indicates semi-annual variation with maxima in solstices and minima in equinoxes.

4. Solar cycle variation

A strong inverse correlation is observed between the annual number of AQDs and sunspot number (R_z), when smoothed over five years by the method of fourth differences. This is noticed from Fig. 3 in which N represents the variation of occurrences during a year and R_z the corresponding sunspot number. Correlation between annual number of AQDs (N) and sunspot (R_z) were computed by successively correlating and lagging in one year steps. The coefficients are shown as a function of lag in Fig. 4. The highest negative correlation coefficient (C.C.) of $-0 \cdot 705$ is obtained for a lag of $+1$ year (*i.e.*, when the annual number of AQDs for the period 1934-1967 are correlated with annual R_z for the period 1935-1968). The minimum in the solar activity cycle appears to follow the maximum in the AQDs after one year. The C.C. is significantly different from zero (least value of C.C. to be significant at 99 per cent confidence level for $n=34$ is $0 \cdot 4182$). From these considerations it is inferred that the maximum number of AQDs during a year occur in the declining phase of solar activity near the solar minimum.

5. Type of variation on AQDs

When the smoothed diurnal variation of H based on hourly values, on individual AQDs are plotted it is noticed that the normal H maximum around local noon is still present, but a secondary maximum appears at a different time. This pattern is found to exist when the mean 'H' magnetorgrams are plotted for all the AQDs grouped according to the hour of maximum. Some typical mean magnetograms are shown in Fig. 5. The amplitudes of the first and second harmonics obtained by Fourier analysis of the mean magnetograms corrected for the non-cyclic change have been computed and plotted against the respective time of maximum in Fig. 6. The harmonics are comparable, when the $S_q(H)$ maximum falls near 1200 or 2200 hr UT. For the normal diurnal variation of $S_q(H)$ with maximum near local noon, the diurnal amplitude predominates and the ratio of the second to the first harmonic is about $0 \cdot 5$ for Alibag. Since this ratio increases to nearly unity for variation with maximum near 1200 to 2200 hr UT, it may be concluded that the nature of the variation tends to be semi-diurnal as the maximum in S_q (H) moves to either side of the local noon.

6. Discussion

Brown and Williams (1969) indicated that the inverse relation of occurrence of AQDs with the sunspot cycle and the absence of equinoctial maxima strongly opposes the cause of AQDs being of magnetic disturbance origin. Olson (1970) showed from theoretical considerations that while the magnetospheric currents make a significant contribution to the amplitude of the diurnal variation, the average pattern of S_q is not affected. And he indicated that the cause is more likely to be in the dynamo S_q current system. The pattern of this current system, which approximately remains in a fixed position with respect to the sun, consists mainly of two big vortices on the sunlit side of the earth, one to the north and another to the south of the equator. These vortices were generally considered to be on an average symmetrical with respect to the equator. There is, however, increasing evidence that these current systems are not only asymmetric between the northern and the southern hemispheres, but extended well beyond the equator in summer and winter solstices (Yacob 1966, Hutton 1967, Matsushita and Maeda 1965) suggested that the effect of the electrojet on the S_q current system in the middle latitudes should be taken into consideration since it is a part of S_q current system. They also found that electrojet does not always flow parallel to the dip equator, particularly during winter and summer months. Osborne (1968) has also shown that the foci of the northern and southern current vortices change from one day to next in phase during equinoxes but independently in winter and summer. The occurrence of abnormal quiet days, with predominance in winter months, could be ascribed to the N-S asymmetry and the day-to-day changes in the current vortices. That the frequency of AQDs is larger in the summer and winter months compared to the equinoctial months may be a consequence of the greater N-S asymmetry in the current vortices and occasionally one distorting the influence of the other. Their frequency during the solar minimum epoch has also been found to be relatively larger. The current vortices during the solar minimum epoch being comparatively weak, these may be easily distorted by fluctuations in the wind and the conductivity of the current layer.

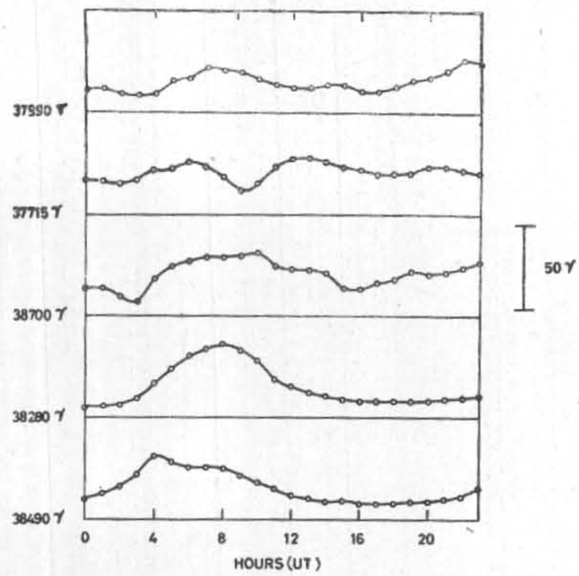

Fig. 5

Mean magnetograms for $S_q(H)$ for days when maximum occurred in the time interval 3-4, 8-9, 10-11, 13-14 and 22-23 hr UT. (reading upwards)

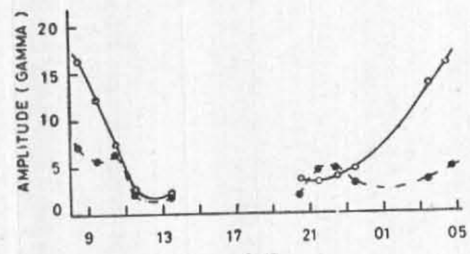

Fig. 6

Variation of amplitude of 24-hr (continuous) and 12-hr (dotted) components of $S_q(H)$ with time of maximum

7. Conclusion

The study of the abnormality in the phase of the $S_q(H)$ at Alibag over a 37-year interval confirms the finding of Brown and Williams at Abinger and three other stations that a strong inverse correlation exists between R_z and the number of AQDs. At Alibag, as also at Trivandrum, the frequency of AQDs exhibits a predominantly semi-annual variation with maxima in winter and summer solstices. The daily variation on AQDs has two maxima one near the local noon and other either on the prenoon or the afternoon side. It is suggested that the N–S asymmetry and day-to-day changes in the S_q current vortices could be the cause of AQDs.

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