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Geomagnetic calm intervals and anomalous solar cycle 20

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Abstract. Long period variations in the occurrence of prolonged intervals of calm magnetic field conditions are studied using index Ap of magnetic activity. The solar-cycle variation in occurrence is compared with the sunspot number. Anomalous behaviour for solar cycle 20, observed in other solar parameters, are shown to be manifested in the occurrence frequency of quiet intervals. Spectral characteristics of occurrence indicates a dominant long period variation of about 30 years and a more feeble 11-year oscillation.

Keywords. Quiet intervals ; geomagnetic activity ; solar activity.

1. Introduction

Long term association of indices of geomagnetic field with solar activity, interplanetary magnetic field (IMF) and solar wind parameters have been extensively studied (Bartels 1963 ; Legrand and Simon 1981 and several others). The spectral characteristics of long series of index Ap of geomagnetic activity and sunspot number (Rz) have also been discussed in detail (Fraser-Smith 1972). *In situ* observations of solar wind and IMF by spacecraft since 1963 have opened out new avenues of such correlative studies and to extrapolate on either side—into the past as well as future— the relationship between surface magnetic field and the solar and IMF parameters. In recent times, geomagnetic activity has also been utilised as a precursor for determining the magnitude of the ensuing solar maximum. Ohl (1976), Sargent (1977) and Kane (1978) have shown linear relationship between indices of geomagnetic activity during the declining or minimum phase of a solar cycle and the maximum sunspot number in the succeeding cycle. Hirshberg (1973), Svalgaard and Wilcox (1977) reported that the dependence of the geomagnetic activity on Rz may differ from one cycle to another. Gosling *et al* (1977) found that while the average features of sunspot variations over a solar cycle has not differed appreciably from cycles 17 to 20, the corresponding geomagnetic activity has shown a radically different behaviour during cycle 20 (1964–1976).
In this paper, we choose an index to represent prolonged intervals of geomagnetic calm and study its long term variation, spectral characteristics, seasonal dependence and relationship with solar activity.

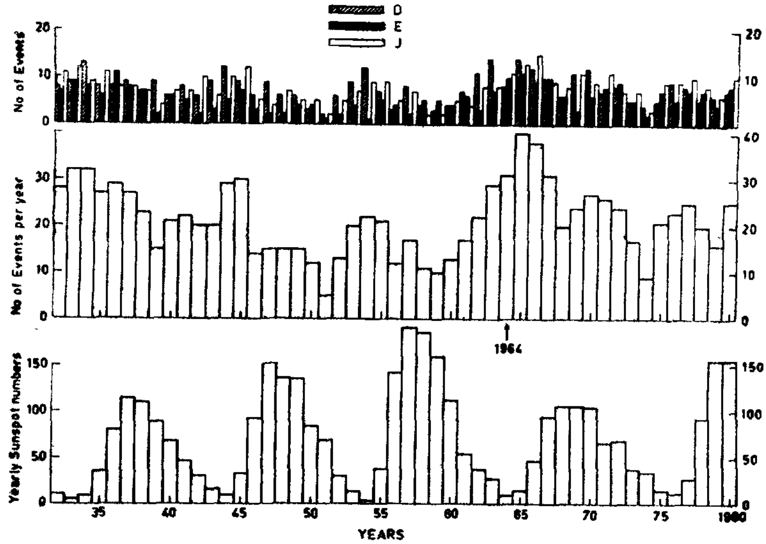

Figure 1. Distribution of total events, their seasonal dependence and yearly mean sunspot number for 1932 to 1980.

2. Data and results

Prolonged intervals of quiescent conditions of geomagnetic activity have been identified as those for which daily Ap value is less than or equal to 7 for at least three consecutive days. These were chosen from the mean daily data for Ap for the interval from 1932 to 1980. Since geomagnetic activity is manifestation of the interaction of solar wind and magnetosphere and energy changes inside the magnetosphere, these intervals may also be considered representative of quiescent conditions of the magnetosphere and solar wind. The solar parameter chosen for comparison was annual Zurich relative sunspot number (Rz) for the corresponding period.

The frequency of occurrence of these events for each year as well as for the three Lloyd's seasons (D for northern winter, E for Equinox and J for northern summer) together with annual mean Rz are shown in figure 1. The most prominent feature of the figure is that, the number of events exhibit peaks close to sunspot minimum. However the overall dependence of the events of Rz is not necessarily anti-phase but is more complex. Ol' (1971), Bhargava and Rangarajan (1975), Sargent (1977) and others related geomagnetic activity of the preceding solar minimum with sunspot maximum of the current cycle, it appears however similar relationship is not valid for the occurrence of quiscent intervals. It is known (Ol' 1971; Crooker *et al* 1977) that geomagnetic activity depicts two peaks in a solar cycle —first due to the flare associated geomagnetic disturbances near solar maximum and the second due to recurrent active regions of the sun more prominent during declining phase. The frequency of occurrence, shown in figure 1, does not always have a secondary peak in the declining phase nor the solar cycle change for different 11 year periods are immediately comparable. So far as the occurrence of quiet

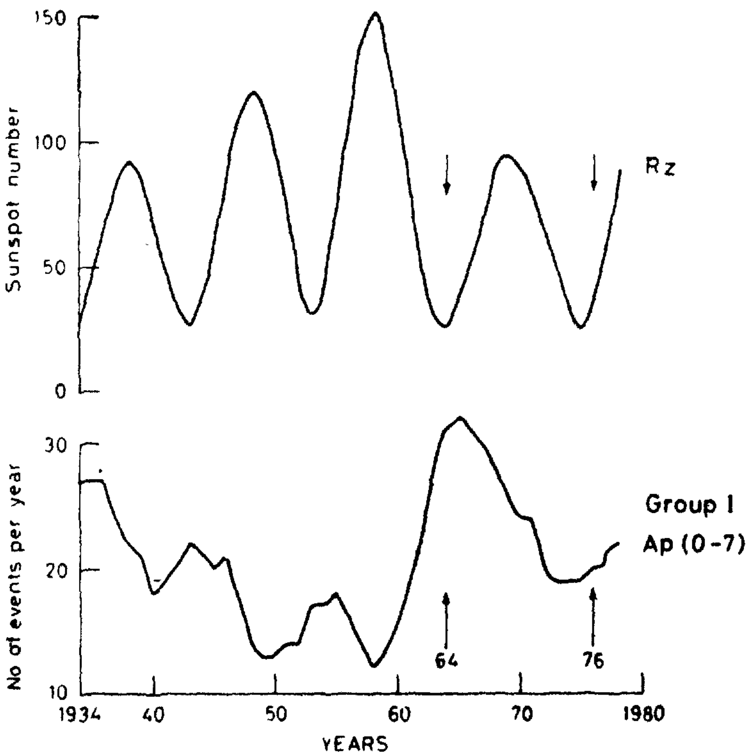

Figure 2. 5 year overlapping mean for events and sunspot numbers.

intervals as a function of season is concerned, the maximum occurrence in each year is rarely noticed in the equinoctial season. This should only be expected as geomagnetic activity tends to maximize during the equinoxes. Though Ap index is more representative of the activity in the northern hemisphere (11 out of the 12 stations used in the derivation of the index are located in the northern hemisphere) and annual variation in the magnetic field is well-known (Malin and Isikara 1976 ; Mayaud 1978) we find that prolonged intervals of quiet conditions have no particular preference for either D or J season.

To bring out the relationship between Rz and the occurrence of events more clearly, we have shown in figure 2, 5-year overlapping mean of the annual mean Rz and frequencies of occurrence. This removes high frequency components effectively. The outstanding feature of figure 2 is the prominent peak of the number of events for the year 1964. The broad pattern in the occurrence for the three solar cycles 17 (1934–1944), 18 (1944–1954) and 19 (1954–1964) is an initial rapid decline followed by a slow recovery towards a maximum. However, for cycle 20 (1964–1976), this broad pattern is absent altogether. Anti-phase relationship between occurrence and Rz is clearly evident up to 1964 beyond which period, this is conspicuous by its absence. This aspect has been brought out more clearly in figure 3, where mean variation in occurrence frequency derived for the three solar cycles 17 to 19 is compared with that for cycle 20. As against the pattern of maximum close to the solar minimum, the occurrence frequency exhibits

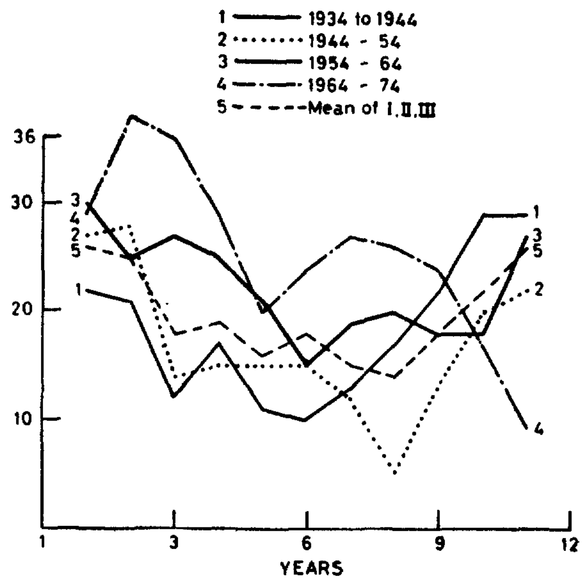

Figure 3. Mean of the events for three solar cycles 17, 18, 19 and yearly mean of events for solar cycle 20.

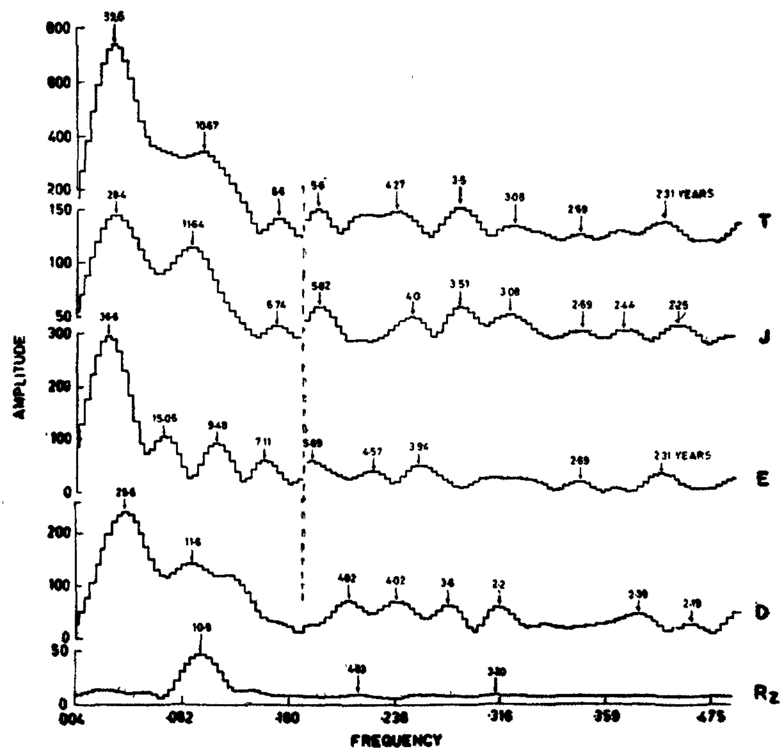

Figure 4. Spectral estimates of total events (T) J season, E season, D season and sunspot number. - - - - - represents change in scale for Y axis.

highly anomalous behaviour for cycle 20. Such an anomaly has earlier been noticed by Gosling *et al* (1977) in the *aa* index and by inference, in the solar wind velocity. Rz itself shows slightly different behavioural pattern for this period in that the solar maximum was spread over three years (1968, 1969 and 1970) having nearly same sunspot numbers—the declining phase was marked by a break in the decreasing trend during 1971 and 1972 and the minimum occurred much later in 1976 (see figure 1). Thus, yet another parameter of surface magnetic field appears to have similar anomalous behaviour during solar cycle 20.

2.1. *Spectral characteristics of the occurrence*

As we have mentioned earlier, the annual occurrence of quiet time intervals shows a complex time variation. This variation appears to be related to the solar activity but not exactly linearly. To identify dominant oscillations in the occurrence pattern, we computed Fourier spectra of the five time series—(i) Annual occurrence frequency, (ii to iv) the seasonal occurrence and (v) Annual mean Rz. The spectra were computed using a version of Fast Fourier Transform adopting a band width of 0·002 for each spectral estimate. These high resolution spectra are shown in figure 4. It is at once apparent that the occurrence frequencies are dominated by a long period oscillation, the periodicity of which varies between 26 to 36 years. The solar cycle signal—(10.5 yr in Rz)—appears clearly only in the J seasonal occurrence, is discernible in D season and in the total but is absent in equinoxes. This is consistent with our earlier statement that occurrence itself was minimum during equinoxes. The longer period variations (of nearly 30 years) and the other high frequency components seen in the occurrence spectra are evidently not linked with the solar activity. From figure 2 it may be inferred that the 30 year periodicity is perhaps the fundamental period in the occurrence of events, the main contribution arising from the anomalous maximum in 1964–65. However, analysis with longer span of data only can establish the presumed 30-year periodicity unambiguously.

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