ENERGETIC FLARE ZONES ON THE SUN

V. K. VERMA, M. C. PANDE, and WAHAB UDDIN

Uttar Pradesh State Observatory, Manora Peak, Naini Tal, India

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Abstract. In this investigation, we have studied the latitudinal, longitudinal (northern and southern hemispheric) distributions based on 1737 major flares observed during solar cycles 19 and 20 (see subsequent paragraphs) and have arrrived at some interesting results which go to show that as far major flares are concerned latitudewise 11–20° belts, and longitudewise 5–8 places are most prolific in producing major flares in each hemisphere. During the above cycles at least 5 flare zones are present in each hemisphere. In fact these zones seem to produce more than 50% of the total number of energetic flares investigated by us and occupy only < 4% area of the Sun.

1. Introduction

The abundance of different types of electromagnetic phenomena that accompany certain Hα flares has led over the years to a systematic organization of this information. Dodson and Hedeman (1971) first introduced an experimental comprehensive flare index. It is based on five components, which when taken sequentially constitute a crude profile of electromagnetic radiation of the flares. The components considered are: sudden ionospheric disturbances (SIDs), importance in Hα, magnitude of 10 cm radio flux, dynamic spectrum (type II and type IV bursts) and magnitude of 200 MHz radio flux. The details of these parameters are given in *UAG-14* by Dodson and Hedeman (1971). Based on the importance of the five components mentioned above, Dodson and Hedeman (1971) called some flares as major flares if the flares fulfil any one of the following criteria: SIDs importance ≥ 3, or Hα importance ≥ 3, or 10 cm flux $\geq 500 \times 10^{-22}$ W m^{-2} Hz^{-1}, or occurrence of type II and type IV bursts (duration 10 min). Further details about these criteria are given in *UAG-14* (1971). Dodson and Hedeman compiled major flares as defined by them for the period 1955–1979 and published them in the form of *UAG-14, UAG-52*, and *UAG-80* (Dodson and Hedeman, 1971, 1975, 1981). Several authors have studied the longitudinal distribution of flare occurrence on the Sun (Waldmeier, 1938; Waldmeier and Bachman, 1959). Waldmeier (1938) also studied the latitude distribution. Since the longitudinal distribution of the flares by these authors were limited to the solar disk, therefore, one cannot draw any conclusion regarding the actual distribution of these flares on the Sun.

In this paper we have studied longitudinal and latitudinal distributions of the major flares on the Sun. Further, we have found 5–8 zones of particularly high flare productivity on the Sun in each hemisphere during cycles 19 and 20. We have also discussed the results obtained in the present analysis.

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2. Observational Data, Analysis, and Results

For studying the latitudinal and longitudinal (in each hemisphere) distribution of flares on the Sun, we have used the data of solar cycle 19 (1955–1965) and cycle 20 (1966–1976) on major flares compiled and published by Dodson and Hedeman as *UAG-14* (1971), *UAG-52* (1975), and *UAG-80* (1981). Over the said period, 1737 flares could satisfy the criteria of major flares. Out of these 1737 major flares, 710 major flares were observed during the solar cycle 19 and 1027 major flares were observed during the cycle 20. Further, out of 710 major flares observed during cycle 19, locations of 602 flares are known in Hα emissions and out of 1027 major flares observed during cycle 20, locations of 885 flares are known in Hα emissions. Sometimes a major flare has two Hα locations. If these locations are within $\pm 5°$ then we treat it as a single flare.

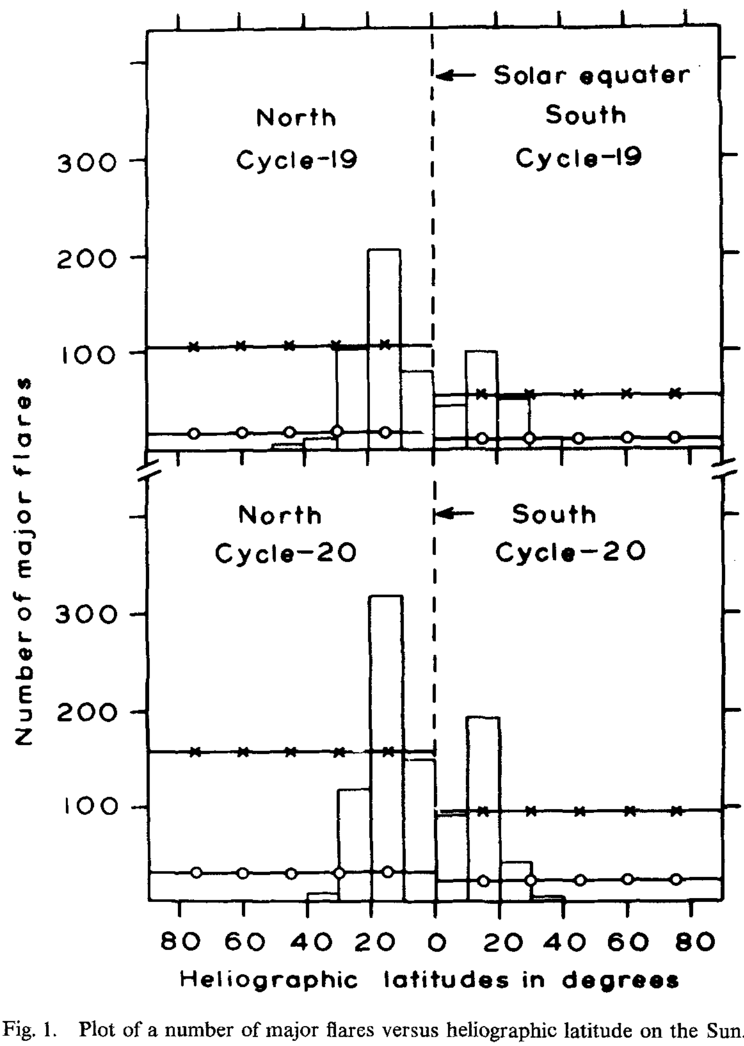

Fig. 1. Plot of a number of major flares versus heliographic latitude on the Sun.

However, if the location of a flare is larger than $\pm 5°$, we count the major flare twice. Since there are very few flares of this type, therefore, the counting or neglecting of these flares does not appreciably modify our results.

The latitudinal distribution of major flares is shown in Figure 1, where the vertical small dashed line shows the solar equator. From Figure 1, it is clear that the northern hemisphere of the Sun was more active than the southern hemisphere during cycles 19 and 20. From the figure it is also clear that the 11–20° latitude strip was significantly more active than other latitudes during solar cycles 19 and 20 in each hemisphere. Now to check the validity of 11–20° peaks in Figure 1, we first suppose that the major flare activities are uniformally distributed along the heliographic latitudes. It it is true the 11–20° peaks should be within the upper and lower mean lines, which are drawn with 99% confidence level. In Figure 2, the upper and lower mean lines with 99% confidence level are shown by a symbol dash and cross and with a dash and circle, respectively. As is clear from Figure 1, the 11–20° peaks as well above the upper mean line. Thus, 11–20° peaks are real activity peaks along solar latitudes.

Longitudinal distributions of major flares during solar cycles 19 and 20, in each

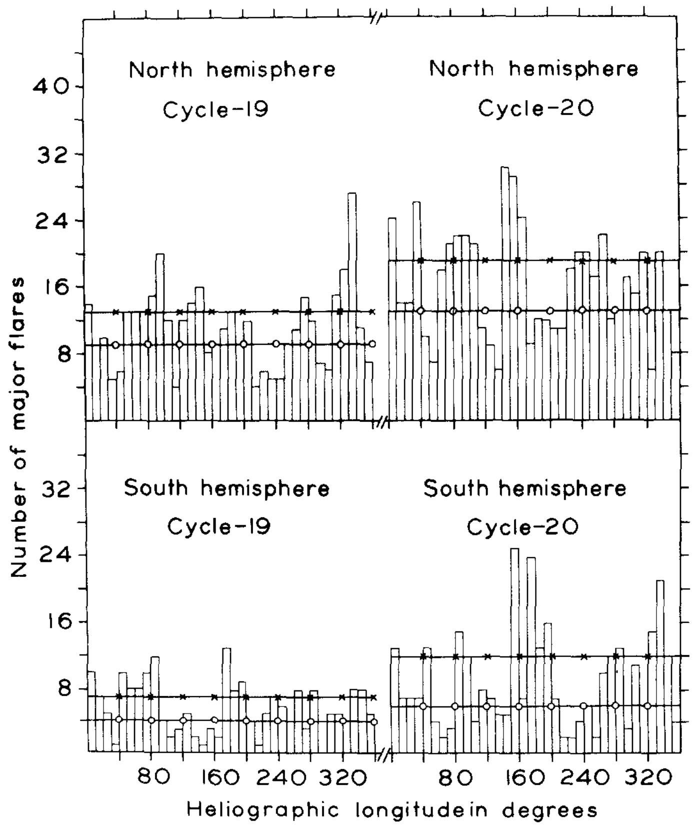

Fig. 2. Plot of a number of major flares versus heliographic longitude on the Sun.

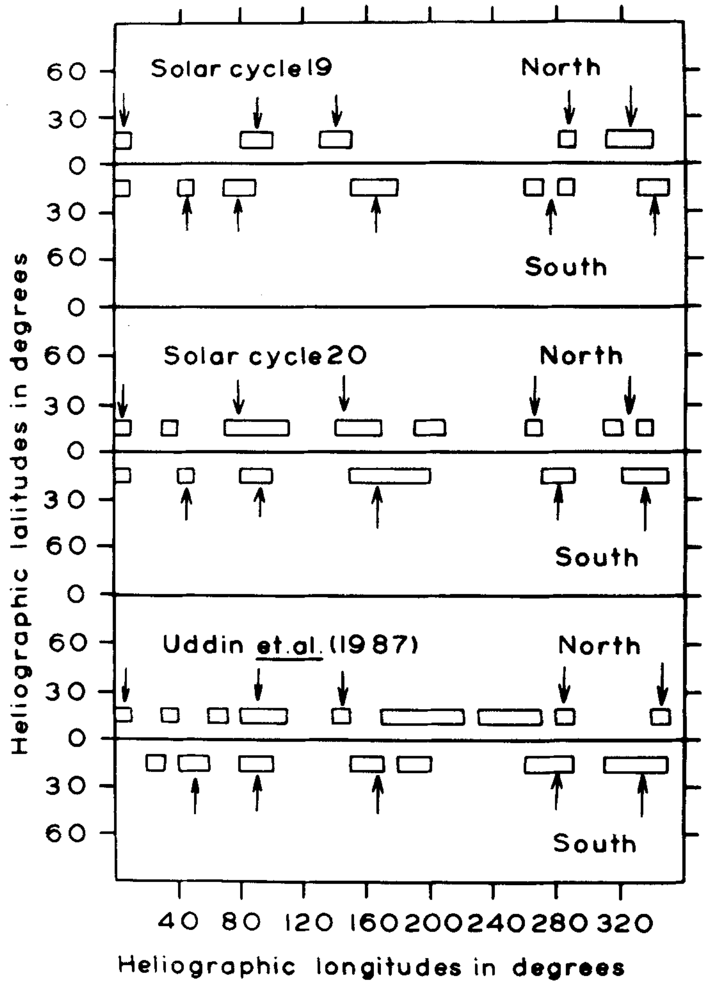

Fig. 3. Location of major flares or energetic flare zones on the Sun.

hemisphere are shown in Figure 2. To arrive at these histograms the longitude of each flare was calculated. It is obvious from Figure 2 that in each hemisphere, at 5–8 places along the longitudinal belt, the major flare activity is profuse. Further, it is also clear from Figure 2 that the significant activity of some peaks in both the northern and southern hemisphere are located alike in longitude belt (Figure 2) within 10°. Now to check the validity of 5–8° peaks in each hemisphere, in Figure 2 during solar cycles 19 and 20, we first suppose that the major flare activities are uniformally distributed along the heliographic longitudes. It is true the 5–8° peaks in each hemisphere in Figure 2 should be within the upper and lower meanlines, which are drawn with 99% confidence level. We have considered a 99% confidence level to ensure that only very strong peaks should be considered as high flare longitudes. In Figure 2, the upper and lower mean lines with 99% confidence level are shown by the symbols dash and cross and dash and circle, respectively. As is clear from Figure 2, the 5–8° peaks in each hemisphere during cycles 19 and 20 are well above upper mean line. Thus, 5–8° longitude peaks are real activity peaks along the solar longitudes. The peaks below the lower mean lines in Figure 2 are low activity areas on the Sun. In Figure 2, one can further notice that the 0–180° longitude belt is more active than the 180–360° longitude belt in each hemisphere on the Sun.

For better understanding of the locations of the real active zones on the Sun, we combined the significant peaks of Figures 1 and 2 and plotted them in Figure 3. From Figure 3 it is clear that in solar cycle 19, there are 5 and 7 significant zones in both the northern and southern hemisphere, respectively. Further, in solar cycle 20, there are 8 and 6 zones in the northern and southern hemisphere, respectively. Since these active zones belong to major flares which are also energetic flares, therefore, we would like to call these active zones as energetic flare zones (EFZs) on the Sun. The EFZ's lie in boxes with zones between $10° \times 10°$ to $10° \times 50°$ (latitude × longitude). More than 50% of total energetic flares occur in these 12–14 EFZ's on the Sun, which cover only < 4% area of the Sun (i.e., visible solar surface).

The salient results of the investigation carried out in this section are briefly as follows:

(1) The latitudinal distribution of the major flares shows that the 11–20° latitude belt is significantly active and produces > 50% total flares of the Sun.

(2) The longitudinal distribution of major flares shows that at 5–8 places in each hemisphere, the activity is most prolific.

(3) In the northern hemisphere at 5–8 places and in southern hemisphere at 6–7 places, the activity is profuse during solar cycles 19 and 20. These EF zones produce > 50% of major flares in < 4% solar area.

3. Discussion and Conclusions

From the above results one may infer that the occurrence of major flares is prolific at 5–8 places on the Sun in each hemisphere. This indicates that there are 12–14 EF zones on the Sun, 5–8 in northern and 6–7 in the southern hemisphere, respectively, during solar cycles 19 and 20.

In the present analysis we have used data published by Dodson and Hedeman (1971, 1975, 1981) for the period covered by solar cycles 19, 20, and a part of cycle 21. The cycles 19 and 20 data for major flares corresponds a period between field reversals. Actually we have selected the data for the above period because we have no option and only the above data for major flares was available to us in the literature. From Figures 1 and 2 we show that the polarity reversal of the Sun does not change the results appreciably, since cycles 19 and 20 when considered separately, yield similar results. Thus, it seems that the change in magnetic polarity of the solar hemisphere does not affect the formation of complex active regions which lead to occurrence of energetic/-major flares on the Sun.

It is well known that the latitudinal distribution for flares does follow the butterfly diagram (cf. Smith and Smith, 1963). However, there are two basic differences in our approach: firstly, we have considered major flares only and have rather restricted the sample by confining ourselves to the most spectacular ones which lie above the 99% confidence level in the corresponding histograms. The occurrence of very narrow latitude strips for such events shows that much larger magnetic activity takes place in the complex active regions of mixed polarities at these latitudes. This is extremely significant because no existing solar activity model would explain such a phenomenon straight forwardly.

Most recently, Uddin *et al.* (1987) have studied the distribution of sunspots over the Sun for the period of 1970–1980 (11 years) and found that 7–9 places in the south and north hemispheres, respectively, are most prolific in activity. In their analysis they considered only those active regions (ARs) which have magnetic fields > 1000 G and spot groups of all types. This is shown in the lower part of Figure 3. If we compare high flare activity zones of solar cycles 19 and 20 with high spot number zones (Uddin *et al.*, 1987) as shown in Figure 3 we see that 5 zones (indicated with arrow marks) in northern and southern hemispheres are consistently present at about same longitudes and latitudes of the Sun. This confirms that the EF zones are real activity zones and regularly present on the Sun. Further we find that along with 5 arrowed EF zones in each hemisphere of Figure 3, there are some high spot number zones which are not correlated with major flare zones for cycles 19 and 20. The high spot number zones which are not correlated with major flares may belong to AF, AP, and BF spot classes (Mount Wilson classification) which are less flare productive (Verma and Shelke, 1985).

As far as the existence of active longitudes is concerned a lot of evidence has been gathered in the past (e.g., Warwick, 1965; Švestka, 1968, etc.). Recently, Verma (1984) and Verma and Pande (1985) have for solar surges hard X-ray solar flares, respectively, indicated the existence of four active longitudes separated by 180° and 30° in pairs. As far as EF zones are concerned no references are available in the literature. Presently the existing models of Parker (1955) and Babcock (1961) and others cannot explain the EFZ's on the Sun. Our investigation thus emphasizes the need for a new theoretical magnetic model for the Sun, which can explain the activity occurring in specific activity zones on the Sun.

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