THE DISTRIBUTION OF SUNSPOTS OVER THE SUN

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Abstract. The distribution of the sunspots for the period 1967–1987 (solar cycles 20 and 21) is presented here. We find that the $\pm 11–20°$ latitude belt is most prolific for the occurrence of various spot types irrespective of magnetic-field ranges. Furthermore, longitudinally sunspots occur most prolifically at six or more places on the Sun. Spatially 7–9 zones are present in each hemisphere (north or south) of the Sun where about 50% sunspots occur and occupy only about 4% area of the Sun. During the above cycles at least 5 flare zones were regularly present in each hemisphere. The existing models cannot explain these active zones on the Sun. Thus, the present analysis emphasizes the need for a new magnetic models of the Sun.

1. Introduction

Sunspots are the main sources of solar activity. These are the centres of an intense localized magnetic field. So the solar active features such as prominences, surges, flares, SIDs, etc., depend almost on the intensity and complexity of the magnetic region present on the Sun at that time. Many investigators reported active longitudes on the Sun. Vitinsky (1969) and Maris (1972) obtained the coincidence of active longitudes of a great number of characteristics like sunspots and flares. Similar results were obtained by Warwick (1965) for sunspots, flares, proton flares, plages, prominences, type-IV bursts, noise storms, etc. Kozhevnikov (1970) also found active longitudes for the kinematic index, characterizing sunspot group motion velocities in latitude and longitude. Morozov and Obashev (1969) and Morozov *et al.* (1973) found longitude distribution periodicities of sunspot groups which were qualitatively different in both hemispheres.

Carrington (1958) discovered the distribution of spots with the sunspot cycle. Maunder's 1922 'butterfly diagram' shows latitude drift of sunspot occurrence as a function of time. Shelke and Verma (1985) reported the drifting of four active longitudes having 60° and 120° longitudinal separations.

Smith and Howard (1967) tried to know the distribution of magnetic regions with the help of Mount Wilson magnetograms classification system for sunspot groups having weak longitudinal fields and strengths less than about 100 G with a resolution of 23 arc sec taken from the Mount Wilson magnetograms during August 1959 to December 1962. They found the distribution of magnetic regions in latitude and that many of the regions with polarities reversed from the usual orientation are confined to the equatorial zone.

In some of the studies done by our group (Verma *et al.*, 1987) and by other investigators (references cited later), evidence has been found which shows that there are strong solar activity zones both in longitude and latitude. The results of these investigations

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regarding both the longitudinal and latitudinal distributions of high solar activity indices have been published recently (Verma *et al.*, 1987; Verma and Pande, 1988). However, the results suggest that the solar activity is appreciably concentrated in the vicinity of 11–20° north and south latitudes and also that there are active longitudes in these strips. A natural question thus arose regarding the distribution of sunspots on latitudinal-longitudinal diagram. This paper reports the results of such a study carried out by us with an aim to know how the sunspots are spread over the Sun's surface. Further in this study we have tried to locate the longitude-latitude boxes on the Sun where the concentration of sunspots is high.

2. Data Analysis and Results

In this study we have taken sunspot data from *Solar Geophysical Data* (SGD) from 1 January, 1967 to 31 December, 1987 (solar cycles 20 and 21).

The longitudes and latitudes both are reckoned in 10° intervals. Gnevyshev (1938) investigated the liftimes of some 3000 sunspot groups using Greenwich observations during the period 1912–1934. The results show that more than half of the groups had lifetimes of less than 11 days. He found that the frequency of occurrence rapidly decreases with increasing lifetime. Kopecký and Kopecká (1984) determined the average lifetimes of sunspot group during the period 1964–1976 on yearly basis for northern and southern hemispheres as well as for the whole Sun. We have counted sunspot groups on daily basis. For example, if any spot group exists for 5 days on the Sun's disk it would be counted 5 times. In this way long-lived spot groups have been counted more times as compared to the short-lived spot groups. Thus the statistics would have to be corrected for this factor. To achieve this, we have divided the total counts of sunspot groups in northern and southern hemispheres for every year by the average lifetime of sunspots. The average lifetime of sunspot groups for the period 1967–1976 is taken from a paper by Kopecký and Kopecká (1984) and for the period 1977–1987 it is calculated on the basis of the papers by Kopecký and Kopecká (1984) and Kopecký (1960).

The plot of number of sunspot groups during solar cycles 20 and 21 versus heliographic latitudes is shown in Figure 1. To know which peaks are significant in Figure 1 we have applied *T*-distribution test and only those peaks have been considered which are above 99% confidence level (CL) line. From Figure 1 it is clear that 11–20° peaks are above 99% CL lines in the northern and southern hemispheres during the solar cycles 20 and 21.

To know the longitudinal distribution of sunspot groups over the Sun, we have plotted the number of sunspot groups against heliographic longitudes for the duration of solar cycles 20 and 21 (Figure 2). The horizontal dashed line in Figure 2 shows 99% CL line and the peaks only above this line are taken as significant. From Figure 2, 7–9 active longitudes appeared to exist on the Sun during the solar cycles 20 and 21.

For a better understanding of the location of sunspot groups over the Sun, we have combined the significant peaks of Figures 1 and 2 and plotted them in Figure 3. From Figure 3 it seems that in solar cycle 20, there are, respectively, 9 and 7 significant zones

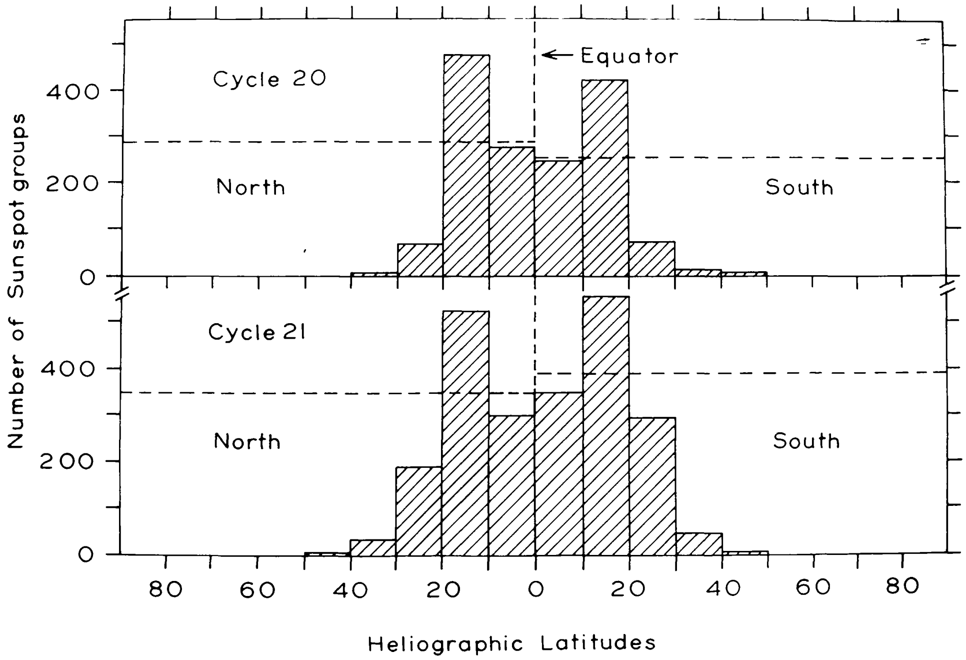

Fig. 1. Plot of number of sunspot groups versus heliographic latitudes.

in both the northern and southern hemispheres. Furthermore, in solar cycle 21, there are 8 zones in the northern and southern hemispheres, respectively. The sunspot zones lie in the boxes with zones 10° × 10° to 10° × 40° (latitude × longitude). From Figures 1 and 3, it is clear that more than 50% sunspot groups occur in these 15–16 sunspot zones on the Sun, which cover only about 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:

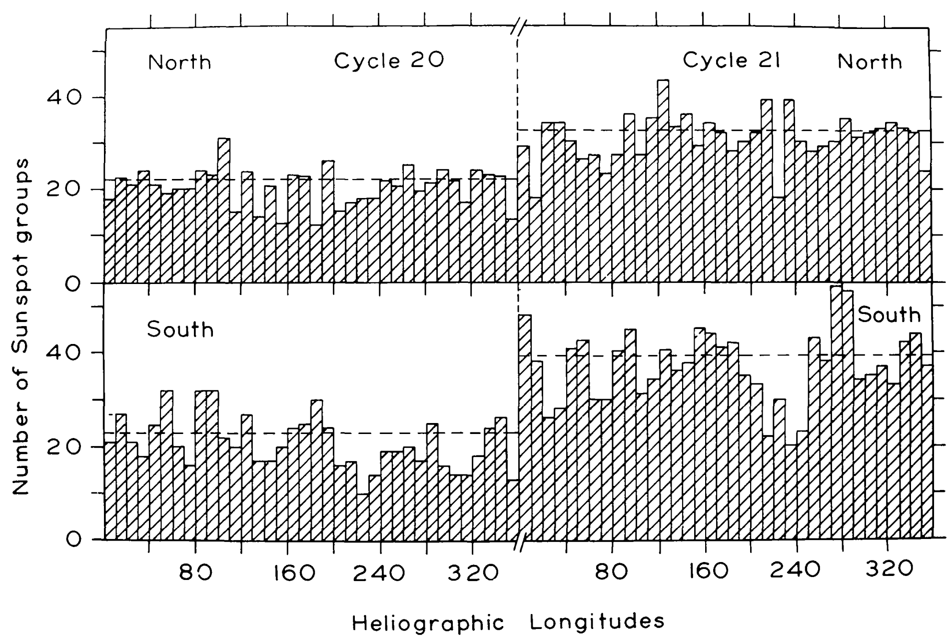

Fig. 2. Plot of number of spot groups versus heliographic longitudes.

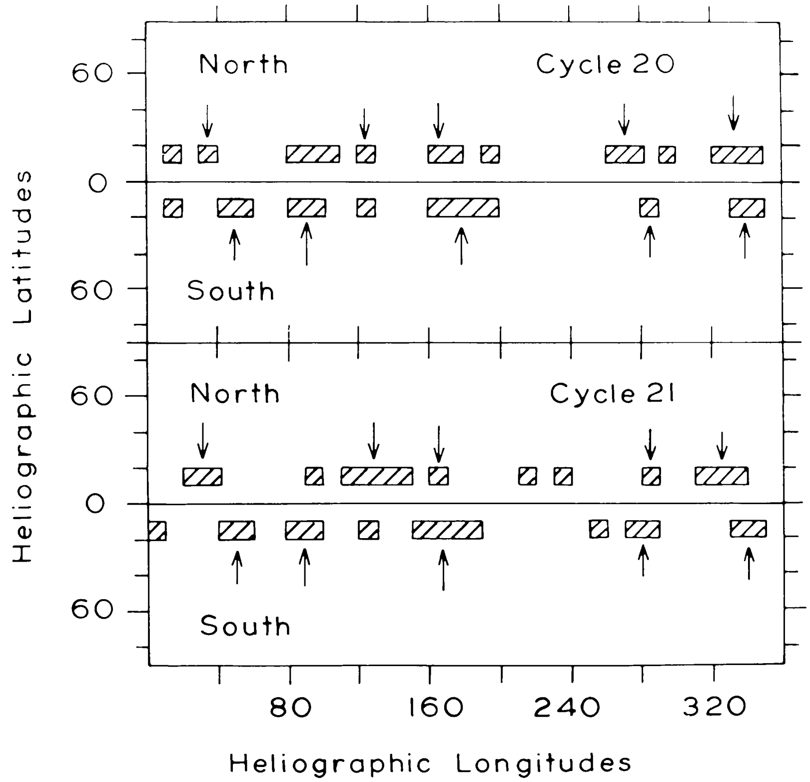

Fig. 3. Locations of sunspot group zones over the Sun during solar cycles 20 and 21.

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

(2) The longitudinal distribution of sunspot groups shows that at 7–9 places in each hemisphere, the sunspot activity is most prolific.

(3) In the northern hemisphere at 8–9 places and in the southern hemisphere at 7–8 places, the sunspot activity is profuse during cycles 20 and 21, respectively. These sunspot zones produce 50% of sunspot groups which cover about 4% solar area.

3. Discussion and Conclusions

Uusually, flares, surges, sprays and active prominences occur in sunspots or near the boundary of the sunspots in the active region. Very rarely flares or other solar activity occurs without sunspots. Therefore, for knowing the spread of solar activity on the Sun, the study of distribution of sunspots over the Sun is of basic importance. In the past, the longitudinal and latitudinal distributions have been studied by many investigators (Carrington, 1958; Maunder, 1922; Kuklin, 1962; Smith and Howard, 1967; Warwick, 1965; Morozov and Obashev, 1969; Vitinsky, 1969; Kozhevnikov, 1970; Trellis, 1971a, b; Maris, 1972; Morozov *et al.*, 1973; and Shelke and Verma, 1985). All these investigators are of the view that the Sun has active longitudes and that the activity is distributed in certain patterns. Keeping the above facts in mind, that the Sun has most probably active longitudes, we have tried to find the nature of activity – i.e., whether it is localized in some definite zones or it is distributed randomly over the Sūn. The present investigation shows that the Sun has 7–9 active zones in each hemisphere. The most exciting result obtained in the present investigation is that in 11–20° latitude strips more than 50% of various type spot groups are found to occur. This suggests that the solar activity is concentrated along belts at 10° on both sides beyond the equator. The concept of such active zones on the Sun is introduced by us for the first time. Similar to sunspot zones, recently Verma *et al.* (1987) and Verma and Pande (1988) found energetic flare zones for major flares and type II radio bursts and these are present at about the same longitudes and latitudes. In Figure 3, we see that 5 zones (introduced with arrow marks) in northern and southern hemispheres are consistently present at about the same longitudes and latitudes of the Sun. This confirms, that the sunspot activity zones are real zones and that they are regularly present on the Sun. The above work of sunspot activity zones and earlier work of Verma *et al.* (1987) and Verma and Pande (1988) showing solar activity zones, are most recently confirmed by Ozguc and Duzgelen (1989). As far as sunspot zones or energetic flare zones are concerned, no investigations are available in the literature. Presently the existing models of Parker (1955) and Babcock (1961) and other cannot explain these zones of 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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