SOME REGULARITIES OF THE OCCURRENCE OF LARGE SUNSPOT GROUPS

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Abstract: The periodicities of sunspot groups with an average area larger than 500 millionths of the solar hemisphere surface and of sunspot with the maximum area larger than 1500 millionths in the years 1874—1964 are studied. The study of the 11-year period and of the double maximum of the 11-year period, according to Gnevyshev, does not result in any special regularity of the occurrence of the large sunspot groups which would allows us to forecast the occurrence of the great active regions on the Sun. One can say that the source of the number of the large spot groups provides evidence of the probable existence of the second maximum of the 11-year period, according to Gnevyshev, which is probably due to the increase in the importance of the active regions.

When studying the occurrence of the large groups of sunspots in dependence on time and heliographic longitude, it was shown that this occurrence of the large sunspot groups provides evidence of the fact that in certain periods the outburst of solar activity occurred on the major part of the solar surface, regardless of hemispheres and heliographic longitudes. These outbursts of sunspot activity may appear in some of the 90-day period maxima of the occurrence of large spot groups. The existence of such a 90-day period has also been proved in this paper.

Introduction

The regularities of solar activity, resulting from the trend of indices derived from the quality and quantity of sunspots, had already been studied many times. This is not only due to the fact that sunspots are considered an important manifestation of solar activity, signalizing the presence of an active region with a larger or smaller probability of occurrence of chromospheric flares, but also to the fact that the relatively very homogeneous material of sunspots can provide a very long series of observations.

The paper by Kopecký (1973) on the periodicity of large sunspot groups, in which the author uses the data from a special publication of the Royal Greenwich Observatory (1955) as the fundamental material, contains the catalogue of sunspot groups from the years 1874—1953 with average areas larger than 500 millionths of the solar hemisphere surface. This catalogue was supplemented by a Catalogue of large groups of sunspots from the years 1955—1964 (Kopecký and Kotrč, 1974) and was made up on the basis of the Photoheliographic Results from the Greenwich Royal Observatory Bulletins, also referred to the groups of sunspots with average areas larger than 500 millionths of the solar hemisphere surface. This complex, covering in extent a very long period of solar activity, may serve us as a good basis for a study of the important solar phenomena, connected with the occurrence of large groups of sunspots.

The 11-Year Period of Large Groups of Sunspots

The trend of some indices of solar activity, derived from the data concerning the large groups of sunspots, is compared with the relative number and the number of groups, originated in every year (i.e., with the frequency of originated groups) during the whole traced period in Figure 1. In the upper part of Figure 1 the full line represents the Wolf number, and the dashed line the numbers of sunspot groups, originated in the given year. The numbers given under the upper part of Figure 1 are the serial numbers of the corresponding 11-year cycle (according to the Zürich numbering). The full line in Figure 1b represents areas larger than 500 millionths (N_{500}) and the height of the black columns is proportional to the annual number of

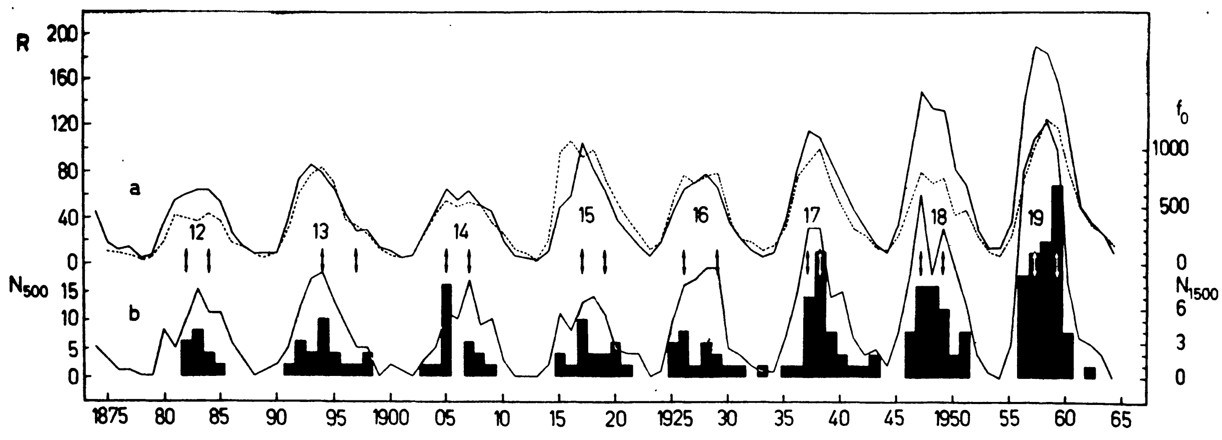

Fig. 1. The trend of the studied indices of solar activity in cycles Nos 12—19. The arrows between part a and b mark the position of first and second Gnevyshev maxima. Details see in the text.

groups with a maximum area larger than 1500 millionths (N_{1500}).

The full curves are in good agreement with the dashed curve (Fig. 1) and the conclusions, made by Kopecký (1967) that the 11-year solar cycle depends, above all, on the periodicity of the occurrence frequency of the solar phenomena, are confirmed. It then follows that all the indices of solar activity, connected with the frequency of solar phenomena by the simple dependence, have to show a very similar trend. This is manifested very strikingly by the trend of the Wolf number. The N_{500} curve is in good agreement with the dashed curve of the frequency of all occurring sunspot groups, in spite of the fact that all smaller groups have been filtered. The course of the annual number of groups with the maximum area larger than 1500 millionths (N_{1500}) is quite complicated. This is given by the very low absolute number of these phenomena and, therefore, by relatively high fluctuations on the one hand, and by the existence of groups reaching the maximum area of 1500 millionths on the opposite side of the solar hemisphere surface, on the other. The short-period change of frequency and the long-period change of the whole importance of these phenomena might play a very substantial role here.

From the data processed in this way, we can deduce that the groups of large sunspots occurred mostly in the vicinity of the maximum of the 11-year cycle. Here, we cannot find any suggestion of the fact that the large spot groups could primarily appear after the maximum of the 11-year cycle, as some observers maintain. The trend of the studied indices of large sunspot groups in the average 11-year cycle, formed from cycles Nos 12—19, is shown in Figure 2. The individual curves were reduced so that their maximum values was equal to 1. The trend of the relative number is given by a full line of N_{500} by the dashed line and of N_{1500} by the dotted line. In order to verify the existence of the double maximum in the occurrence of the large spot groups, the average 11-year cycle was constructed in the following way: The years of the first maximum (upper part of Fig. 2) and the years of the second maximum (lower part of Fig. 2) of the individual 11-year cycles, determined by Gnevyshev and Antalová (1965), were identified. The average 11-year cycle, reduced in this way, shows a double maximum in the lower part of Figure 2, in the trend of N_{500} as well as N_{1500}, while the relative number in the same picture has no double maximum. The absence of the double maximum in the upper part of Figure 2 is evidently

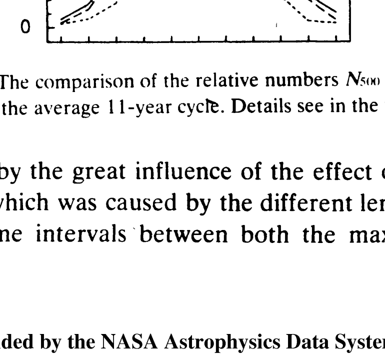

Fig. 2. The comparison of the relative numbers N_{500} and N_{1500} in the average 11-year cycle. Details see in the text.

given by the great influence of the effect of blurring, which was caused by the different lengths of the time intervals between both the maxima in different 11-year cycles. From the lower curves of Figure 2 one can conclude that the large groups of spots in the individual 11-year cycles have a tendency to show the double maximum, according to Gnevyshev, and that the second Gnevyshev maximum is very probably caused by the increase of the importance of the active centres, as pointed out by Kopecký and Kuklin (1969).

The Outburst of Sunspot Activity

In studying the dependence of the large groups of sunspots in cycle No. 19 on the heliographic longitude and on time, a very interesting regularity was found. The positions with the occurrence of sunspot groups, which reached an average area larger than 500 millionths during their development on the visible part of the solar hemisphere, were plotted into the graph. Its vertical axis represents the Carrington heliographic longitude and the horizontal axis is the time axis. In order to obtain information on the daily areas of all groups, chosen in this way, the real area of the corresponding group was plotted in the same graph on the chosen scale for every day.

In tracing this graph we found the following: After the time intervals in which the distribution of the large groups in the heliographic longitude is more or less random and rather sporadic in time, the activity of the large groups suddenly increases. This is primarily manifested by the increase of the numbers of large groups, which occurs simultaneously on a large part of the solar surface. Practically in all heliographic longitudes, regardless of hemisphere. This phenomenon then lasts for one to three rotations of the Sun.

In Figure 3 we can see the part of the graph where an outburst, lasting for one solar rotation, occurred from April 3 to August 31, 1957. A very

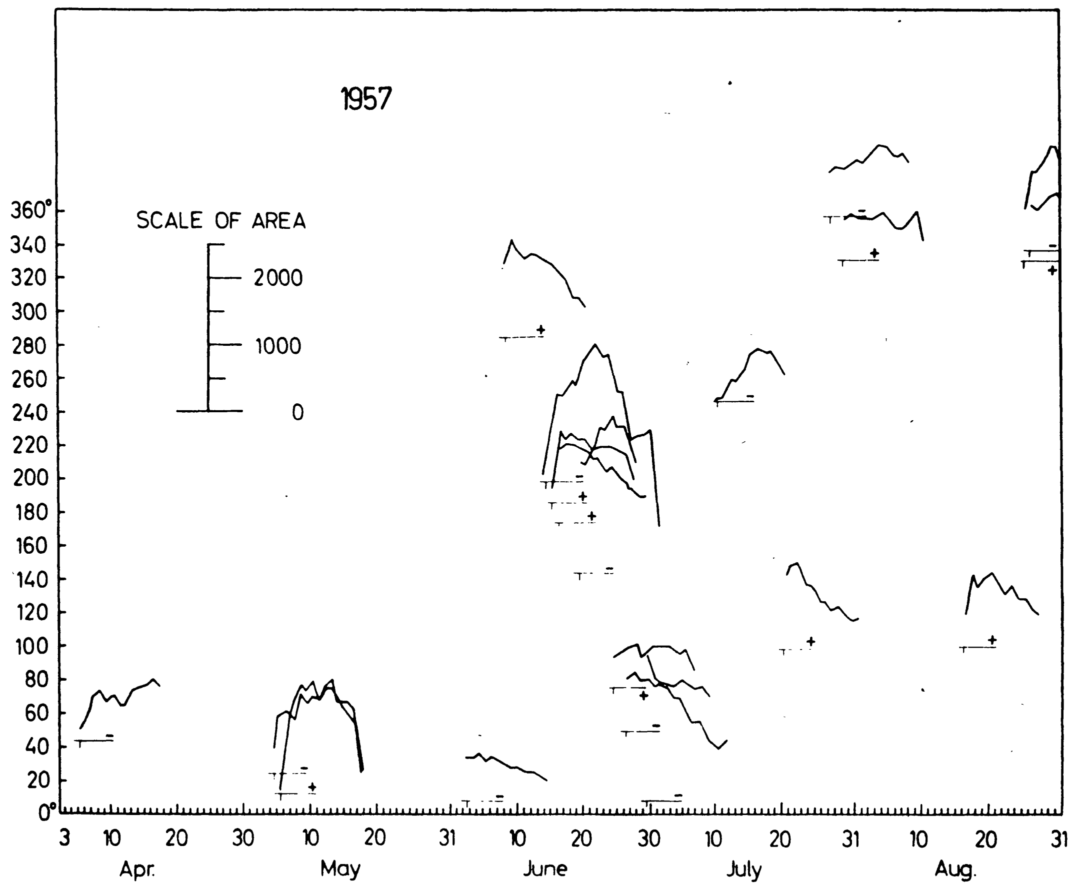

Fig. 3. Graph showing one of the outbursts of sunspot activity in the year 1957, lasting from June 2 till July 10. This is given on the x-axis, the heliographic longitude on the y-axis. The heliographic longitude of every group is represented by the horizontal line segment. This line segments is also the zero level for the daily area of this group. The development of the group area is given in millionths of the solar hemisphere surface. The sign + (or −) designates that the sunspot group occurred in the northern (or southern) hemisphere.

similar picture for the period from July 1 to November 11, 1959 was published in a paper by Kopecký and Kotrč (1974).

To express this regularity quantitatively, we have constructed an index which gives us a good picture of the gradual changes of the activity of large sunspot groups. Let us, first of all, describe the construction of the index on the basis of the graph mentioned above. From the graph, containing the positions, where the large groups appeared in time and heliographic length, a 27-day interval was chosen for every day (i.e. the day, for which the index is determined, ±13 days on the time-axis). In this interval all the positions of the groups, marked in graph, were summed up. The number, representing the sum, is taken as the value of the index for the corresponding day, which may also be defined in this manner: n_i new large spot groups appear on the solar disk (i. e. originated or brought by rotation), on day i, the index N_j for day j is given by the formula

$$N_j = \sum_{i=j-13}^{j+13} n_i .$$

On the whole, the index tells us, how many large sunspot groups have originated, or existed on the visible hemisphere of the Sun during the considered 27-day period.

This index for the years 1956—1960 is given in Figure 4. The areas in which the index exceeds 5 and which are identical with the outbursts (mentioned above) are shaded. From Figure 4 one can very clearly see the 90-day period of this index, proved even by the preliminary autocorrelation analysis. Kleczek (1950) has found a very similar periodicity (89 days) in the occurrence of great flare regions in the years 1935—1974.This is in good agreement with the fact that chromospheric flares occur primarily in the vicinity of large groups of sunspots. Letfus (1975), in his paper presented at this conference, found periods of about 90 days in the trend of the daily areas of sunspots in the years 1883—1954. There is no doubt that the 90-day period of the occurrence of large sunspot groups should also be manifest in the trend of the daily areas of all groups, because the large groups contribute, for the greatest part, to this area.

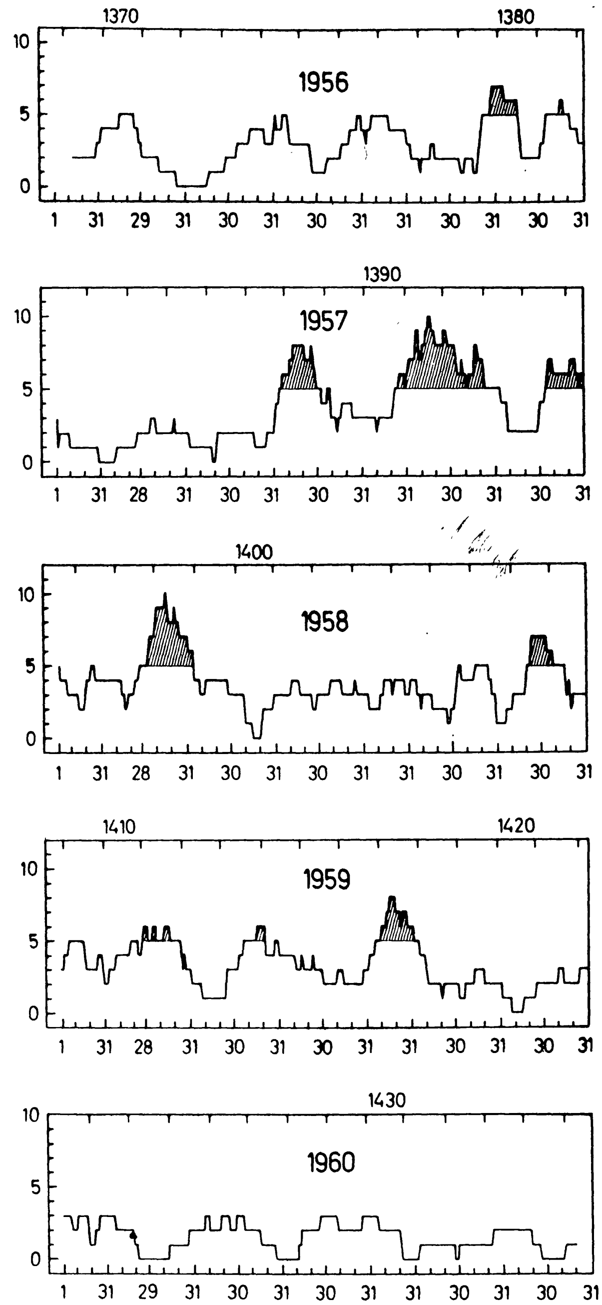

Fig. 4. Index N during the years 1956—1960. The time-scale is expressed in current months (lower scale) and in Carrington rotations (upper scale).

Conclusion

On the whole, we may draw the following conclusions:

1. Outbursts of sunspot activity occur in certain periods. These outbursts are characterized by the origin of large sunspot groups practically in all heliographic longitudes with durations of one to three solar rotations.

2. The index N of large sunspot groups has a 90-day period and, provided that outbursts of sunspot activity occur, they are identical with the maximum of the 90-day period.

3. One may conclude that the 90-day period of the occurrence of great flare regions, found by Kleczek, and the 90-day period of the daily total area of spots, found by Letfus, is a consequence of the 90-day period of large spot groups.

Our results concerning the study of the outbursts of sunspot activity have to be considered as preliminary. This question will be studied further and a more complete analysis will be published in the BAC later on.

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