Distribution of coronal holes over the solar surface 1970–1991

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Abstract. The latest catalogue of coronal holes (hereinafter CHs) was analysed to find long-term and large-scale regularities in the latitudinal and longitudinal distributions of this phenomenon. A systematic displacement of the CHs frequency curves and different trends of this displacement were found when analysing the CHs according to their size and helio-latitude. The longitudinal distribution of the CHs shows two very flat maxima, and the global changes of the area covered by coronal holes are discussed in relation to the 11-year solar cycle. The analogy of the CHs latitudinal and longitudinal distributions with that of the green corona low brightness regions (hereinafter GCLBRs) is indicated and physically substantiated.

Key words: coronal holes – solar corona – solar cycle

1. Introduction

The catalogue of coronal holes (Sanchez-Ibarra and Barazza-Peredes, 1992) was treated to reveal the latitudinal and longitudinal distributions of the CHs over the solar surface. Only the dimensions and shapes of the holes situated within $\pm 60°$ heliographic latitude were taken into account in analysing the Catalogue data. We have arbitrarily classified the CHs into five groups according to their size (1–100, 101–300, 301–600, 601–1000 and 1001 and more square degrees) to obtain summary areas of the CHs (see Figure 3). In doing this, the type of the holes (E, D, I, C, R, as given by the authors of the Catalogue) was taken into account and the size of the holes was duely normalized according to the shape of the CHs' type. In fact, normalization consisted in reduction of the hypothetical rectangular area of the CHs by coefficient 0.4 for E-type, 0.8 for D, 0.4 for I, 0.75 for C and 0.3 for R-type holes. It should be pointed out that there are no data for Carrington rotations 1611–1622. Shorter intervals not covered by the data (see Tab.1 – *Data sources* – in the Catalogue) are not considered in our resulting graphs.

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It is a well-known fact that the coronal holes are characterized by relatively low temperatures and densities of their plasma. Similarly, the intensity of the green coronal emission line Fe XIV 530.3 nm is directly proportional to the density and temperature of the coronal plasma. That is why the GCLBRs, as analysed by Sýkora (1992), should display properties similar to those of the CHs. In spite of the clear physical affinity of both the phenomena, no exact one-to-one correspondence should perhaps be expected. However, a statistical approach to the data could demonstrate more or less convincing resemblance. Unfortunately, the overlap of both the sets of data is short, practically covering the 1973–1976 period only. The rather good identification of CHs and GCLBRs during the Skylab period (1973–1974) has already been reported (Letfus et al., 1980).

This study was motivated by the effort to look for affinity of the large-scale and long-term distributions of the CHs and GCLBRs, by analysing a longer set of CHs data and, thus, to indicate the possibility of using daily patrol measurements of the green line intensity instead of the rather irregular observations of coronal holes, if we are interesting, for example, in the responses of CHs in interplanetary space and in the field of solar-terrestrial physics. We are of the opinion that the results of the present study are another positive verification of the above-mentioned CHs and GCLBRs affinity.

2. Results and Conclusions

Histograms of coronal holes, divided into five groups according to their size, are separately drawn (Figure 1, above) for three latitudinal belts (N60–N20, N19–S19, S20–S60). This way of presentation is very similar to that of the GCLBRs (Figure 1, below), as taken from Sýkora (1992), and allows us to draw the following conclusions:

(1) As expected, the frequency of both the phenomena evidently exhibits 11-year solar cycles in all the three belts for all sizes. Of course, these cycles are by no means identical in time with the sunspot cycle, as shown at the bottom of Figure 1.

(2) The observed systematic displacement of the frequency-curves maxima (indicated by the slopes of the almost vertical dashed lines) between the smallest (class 1) and the largest (class 5) CHs and GCLBRs surprisingly amounts to several years.

(3) The most remarkable point to notice is probably the fact that the displacement of the curves in the equatorial zone (N20–S20) is opposite to that in the higher-latitude zones. At this moment we have no appropriate explanation for this evident reality in terms of the current models. We do not exclude that the pattern found is simply the consequence of Spörer's law geometry, as it is known for active phenomena on the solar surface.

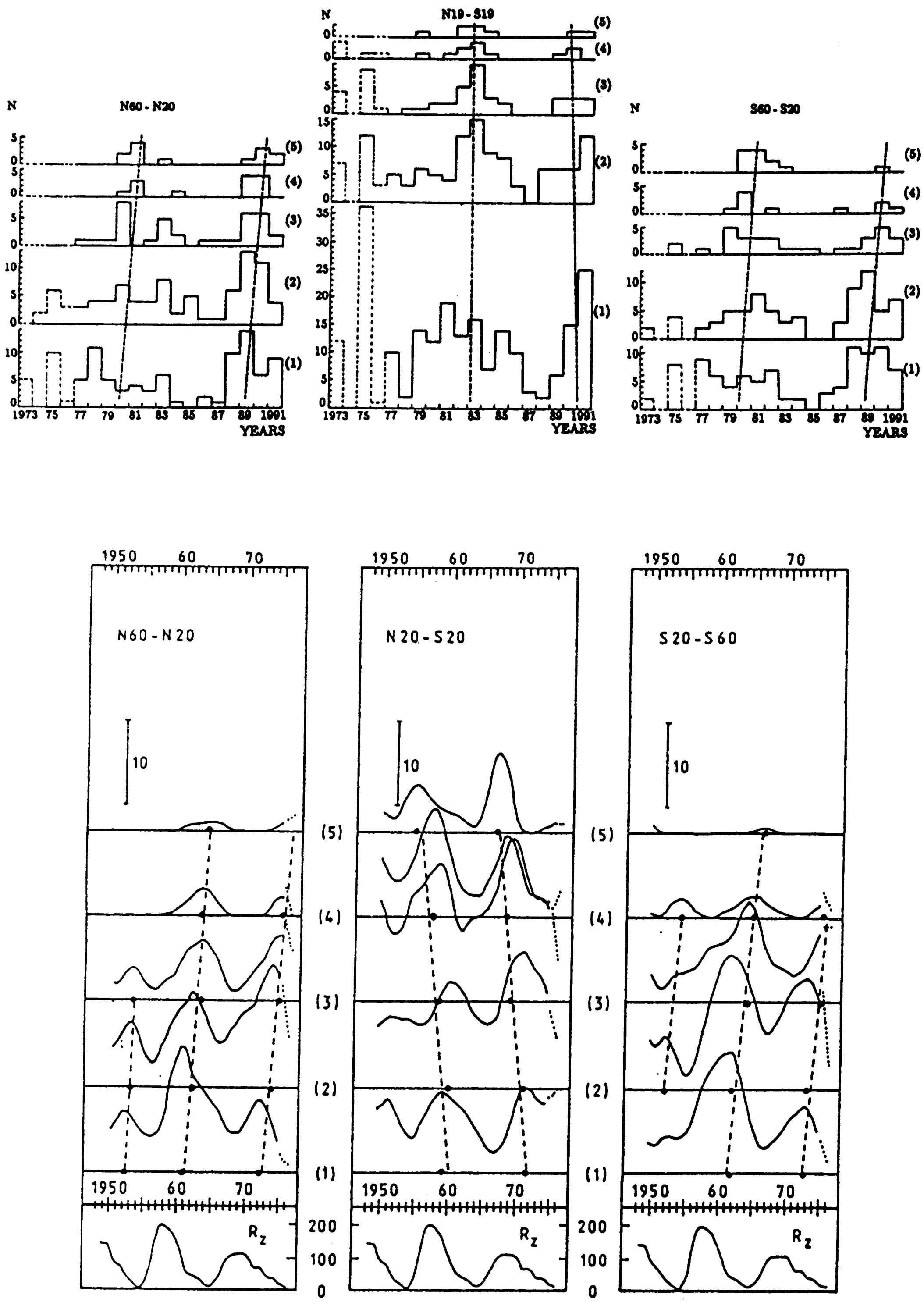

Figure 1. Distribution of the CHs (above) and GCLBRs (below) according to their sizes in three different latitudinal zones

Both phenomena in Figure 1 seem to show more or less similar behaviour. Owing to the smaller statistics, all the three conclusions are perhaps less convincing in the case of coronal holes. Besides, unlike the GCLBRs, where the inclinations of the dashed lines were calculated, the vertical dashed lines in the case of CHs (upper part of Figure 1) should also be mathematically optimized (here they are drawn by hand only). However, this procedure would only become realistic after some years, when it is hoped that further additions will be made to the profiles of the CHs histograms.

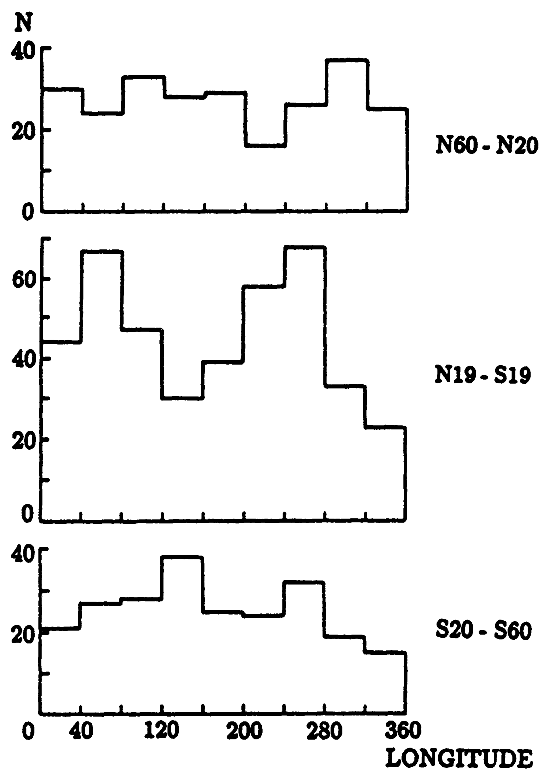

Figure 2. Longitudinal distribution of the coronal holes in three latitudinal zones

The longitudinal distribution of the CHs is shown in Figure 2 (we have chosen a 40° increment in longitude to construct these histograms). Again, it seems to be true that the CHs are not distributed randomly over long periods of time. Some degree of imagination allows one to see two maxima in the histograms. They are statistically significant namely in the equatorial zone N19–S19 (for this purpose we have performed the χ^2 and Kolmogorov–Smirnov tests at the 0.05 significance level). The maxima found, by the way, agree well with the two longitudinal CHs maxima found recently by Bumba et al. (1993). Their maxima are centered at 90° – 120° and 270° longitude, but the authors do not distinguish between latitudinal zones. Our maxima in the higher-latitude zones seem to be shifted to the right in comparison with those of the equatorial zone. This fact is evidently a consequence of the different slopes of the almost vertical dashed lines in Figure 1 at the equator and at higher latitudes. In contradistinction to the well-known "active longitudes" of some solar phenomena, our maxima in Figure 2 indicate a long-term presence of the CHs in the discrete intervals of the "non-active" heliographic longitudes.

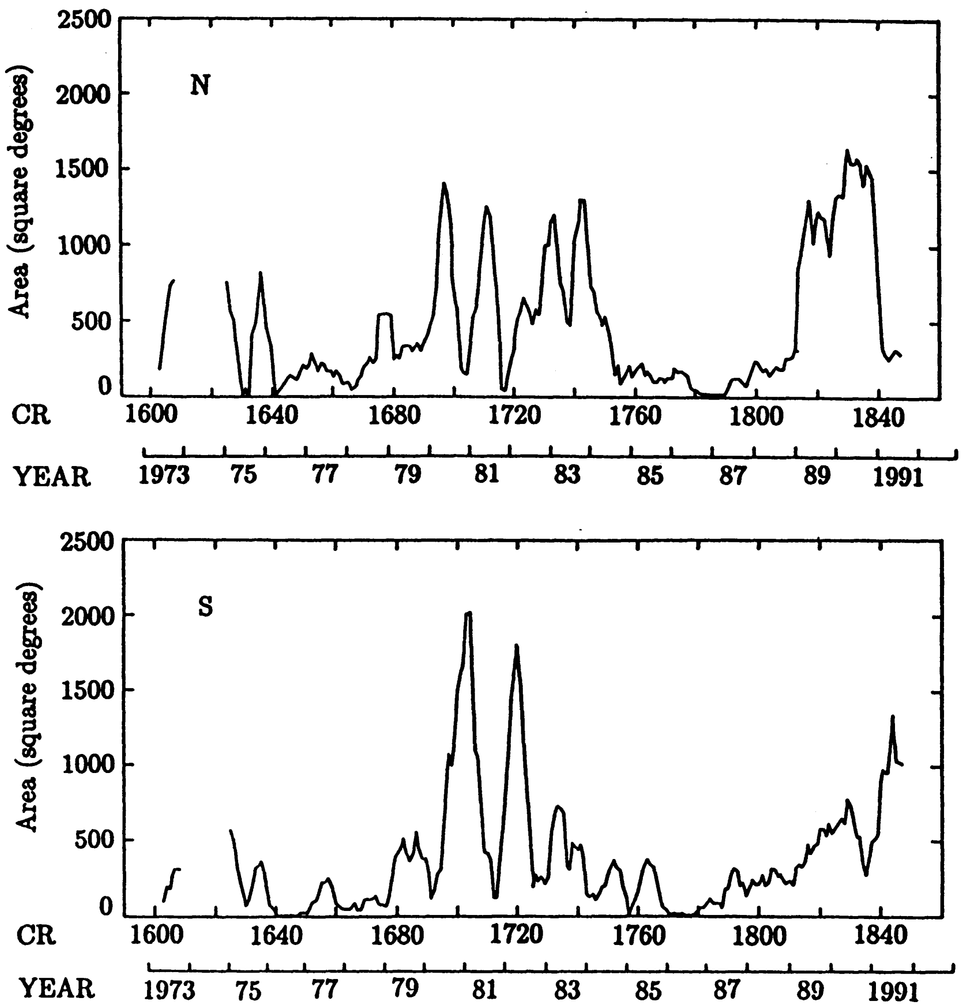

Figure 3. The course of the five-rotation running averages of the CHs summary areas

As already mentioned in Section 1, we have estimated summary areas of all the CHs for each Carrington rotation. The curves of the five-rotation running averages are shown in Figure 3 separately for the northern (N) and southern (S) hemispheres. The large summary areas of the holes at the end of the 21st cycle (1980–1984) are in agreement with the present concept of cyclic variations of the

CHs. At this moment it is difficult to explain another maximum in 1989–1991. A full explanation of the CHs' area behaviour in the 22nd solar activity cycle seems to be premature at this time. Although there are, of course, differences in the details of the CHs area curves, as shown in Figure 3 separately for the N and S hemispheres, the global trends are the same. Additionally, we have estimated the CHs areas considering simply that the holes are rectangulars within the limits of longitude and latitude, as given in the Catalogue. This was done to be sure that our procedure of CHs area normalization, as described in Section 1, is not very subjective. Finally, both the approaches yield identical results. Our conclusion can be compared with the curves of McIntosh et al. (1992) obtained in an independent way from observation of the holes in He 10830. Their results are at least roughly similar.

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