On the problem of the secondary polar zone of prominence activity

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Abstract. The time-latitudinal distribution of the number and area of prominences observed at Lomnický štít coronal station during the period 1967-1991 has been studied in order to check if the secondary polar zones of prominence activity can be traced. The results show that the secondary polar zone appears in one of the hemispheres during the ascending phases of solar cycles 20 and 22. Possible connection of the double structure of the prominence polar zone with the threefold occurrence of the high-latitudinal magnetic field of the Sun is discussed.

Key words: the Sun – prominences

1. Introduction

Solar prominences are seen in H-alpha on the limb as bright phenomena of various shapes reaching heights of up to 10^5km. Their property to appear in all heliographic latitudes and to outline the border between magnetic fields with different polarity makes them suitable tracers both for the large-scale pattern of the background magnetic field and lately for studying the extended solar cycle.

The fundamental regularities of the surface distribution of the prominences and their projections on the disc - the filaments - have been reviewed by De Jager (1962). In this contribution we study mainly morphological properties of the polar zone prominences. These zones and their poleward migration was discovered by Secchi (1872). According to Waldmeier (1957) the poleward migration of the polar zone follows the same law in every cycle, independently of the maximal amplitude of the cycle: at the beginning of a new sunspot cycle the polar zone in a given hemisphere forms at latitude about 45° and begins to move with slight acceleration to the pole.

Waldmeier (1973), however, pointed out that cycle No. 20 has shown an anomaly in polar prominence surface distribution, since two zones had formed in the northern hemisphere, the second zone following the first with a delay

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of 2.5 years. Here we study the time-latitudinl distribution of the number and area of prominences observed at Lomnický štít coronal station over the period 1967-1990 in order to check if a secondary polar zone can be traced for cycles 21 and 22. We also discuss whether this anomaly reflects the three polar magnetic field reversal.

2. Observational and theoretical considerations

It is well known that solar prominences are concentrated into three relatively narrow zones which display different behaviour in the course of the solar cycle activity. The first zone, consisting of the so-called sunspot-type prominences, is situated in the sunspot zone and displays the time-latitude behaviour of this zone. The second zone, consisting of long-lived prominences, is situated about 15° higher than the sunspot zone and migrates towards the equator parallel with it. The third zone, which is of particular interest in this paper, is the polar zone of prominences. It forms at latitudes higher than 45° and, contrary to the above-mentioned zones, migrates to the poles and is phase-shifted to them. The polar zones originates some years ahead of the sunspot minimum and, until the following maximum, migrates towards the pole, reaches it and disappears.

It seems that these two types of prominences zones have different dynamics and probably also different physics, especiallyt since the change of the polarity of the general magnetic field of the Sun has been observed to occur (Waldmeier 1960) when the polar prominence zone reaches the circumpolar regions.

The polar zone is filled mainly by magnetic fields with following polarity. Howard and La Bonte (1981) and Topka et al. (1982) have already shown that the polar magnetic fields are remnants of the following polarity magnetic fields expelled from the main equatorial zone of activity. However, as shown by Giovanelli (1982), the opposite polarity field, whose magnetic flux is about one tenth of that of the main polarity, is always present in the unipolar fields. Therefore, it is quite possible that the occurrence of the double structure in the polar prominence zone is related to the threefold reversals of the high-latitude magnetic field of the Sun in the epoch of the solar cycle maximum.

The time-latitudinal distribution of the prominences traces the large-scale regularities of the magnetic field distribution which also makes them suitable for studying the extended solar cycle, lasting 18-22 years (Wilson 1987, Snodgrass 1987, Makarov et al.1987). According to Bumba et al. (1990) one complete cycle of activity of photospheric magnetic fields covers about 15-17 years. The high-latitude following magnetic fields represent the last evolutionary phase in such a cycle. Therefore, the polar zone of prominences traces the last evolutionary stage of the magnetic cycle.

3. Observational data and method of analysis

We have used the data of regular limb observations of solar prominences carried out at Lomnický štít coronal station with the 20-cm coronograph in the years 1967-1991 (partly published by Rušin et al. 1988).

In studying the time-latitude distribution of the prominences (number and area) we used the method of constructing contour maps with different degrees of smoothing.

4. Results and discussion

Time-latitudinal distributions of the number and the area of the prominences are shown in Figures 1 and 2. The degree of smoothing and the contour levels have been chosen to emphasize the large-scale tendency in the distribution. the following peculiarities can be traced.

Firstly, there is the N/S asymmetry in the number and area distribution for solar cycle (Figure 1, rotations 1520-1530, and rotations 1620-1640) with northern excess, and for cycle 21. Interesting in the N/S asymmetry for cycle 22 (Figure 2) about the epoch of the maximum: southern excess for the interval rotations 1790-1810, change of sign of asymmetry about rotation 1815, and strong nothern excess from rotation 1815 to rotation 1835. Secondly, bifurcation in the prominence distribution is seen at latitudes $\pm 40°$ - $\pm 50°$, in the epoch of the minima of the 11-year cycle, particularly in rotations 1770-1790. Two branches in each hemisphere, one branch proceeding to lower latitudes and the other diverging towards the pole, are formed after the bifurcations. This may reflect the interaction of the old and new cycle of the solar activity at the beginning of the sunspot activity (Bumba et al. 1990), where the equatorial prominence zone of the new cycle separates from the polar prominence zone belonging to the old cycle at dividing latitudes around $\pm 45°$. It is interesting to poin out that, according to Bumba et al. (1990), the oppositely moving systems of patterns - torsional oscillations and polar prominence zone - cross during the minimum at the same "critical' latitudes of about $\pm 45°$.

The time-latitudinal distribution of the polar zone prominences are shown in Figures 3 and 4 (number), and in Figures 5 and 6 (area). The degree of smoothing and the contour levels have been chosen to emphasize the tendency to form a double structure in the polar zone.

As can be seen in these Figures, the second polar zone forms during the ascending phase of cycle 20 in the northern hemisphere and of cycle 22 in the southern hemisphere.

The northern polar zone of cycle 20 shows two branches: the first one reaches the pole in the interval between rotations 1540 and 1550, i.e. shortly before the sunspot maximum, and the second branch reaches the pole during the epoch

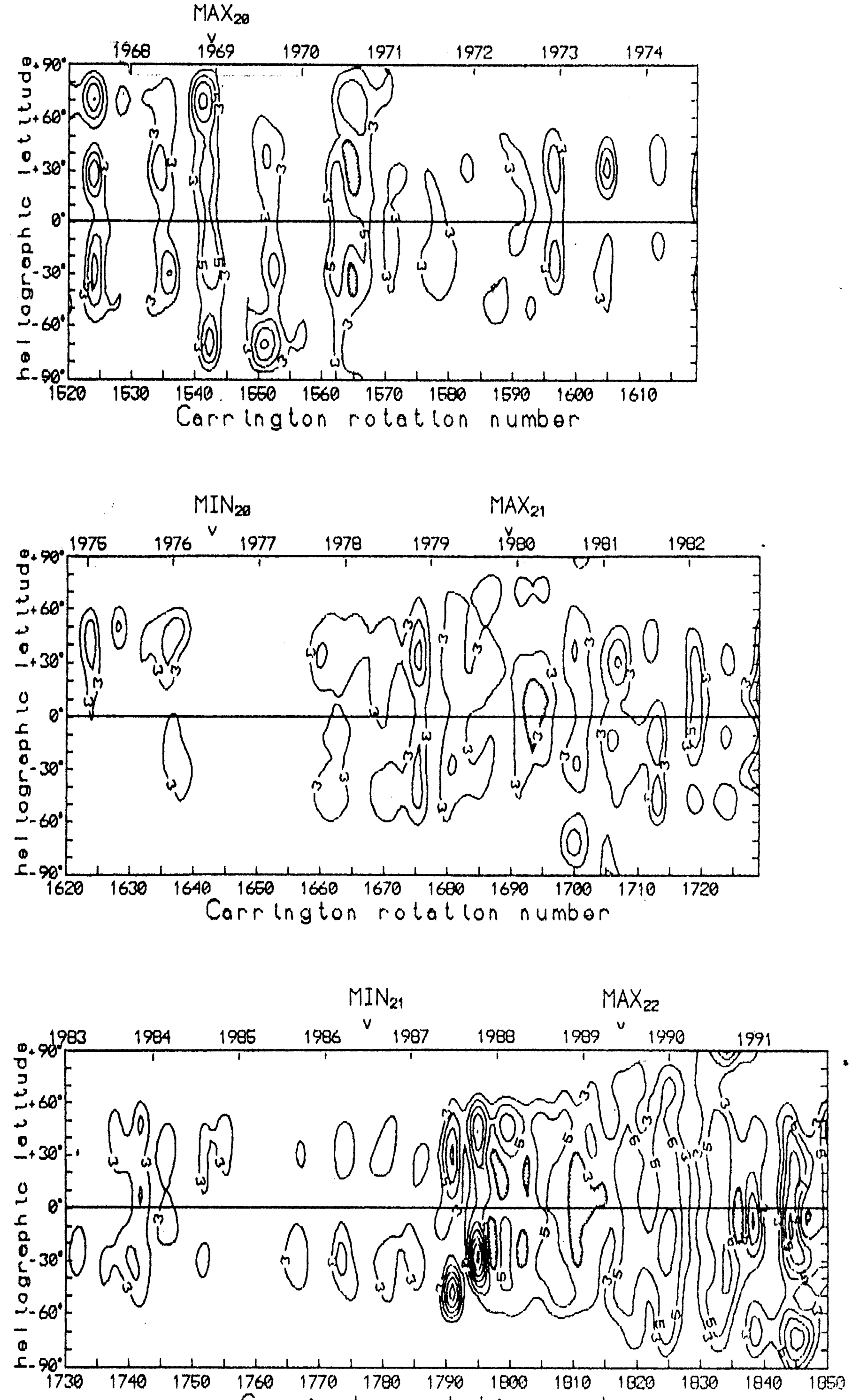

Figure 1. Time-latitudinal distribution of the number of prominences for the years 1967-1991. Prominence numbers have been counted for 1 Carrington rotation time interval in 5° latitude strips. The minimum contour level shown is 3 prominences per grid cell, the contour interval is 2.

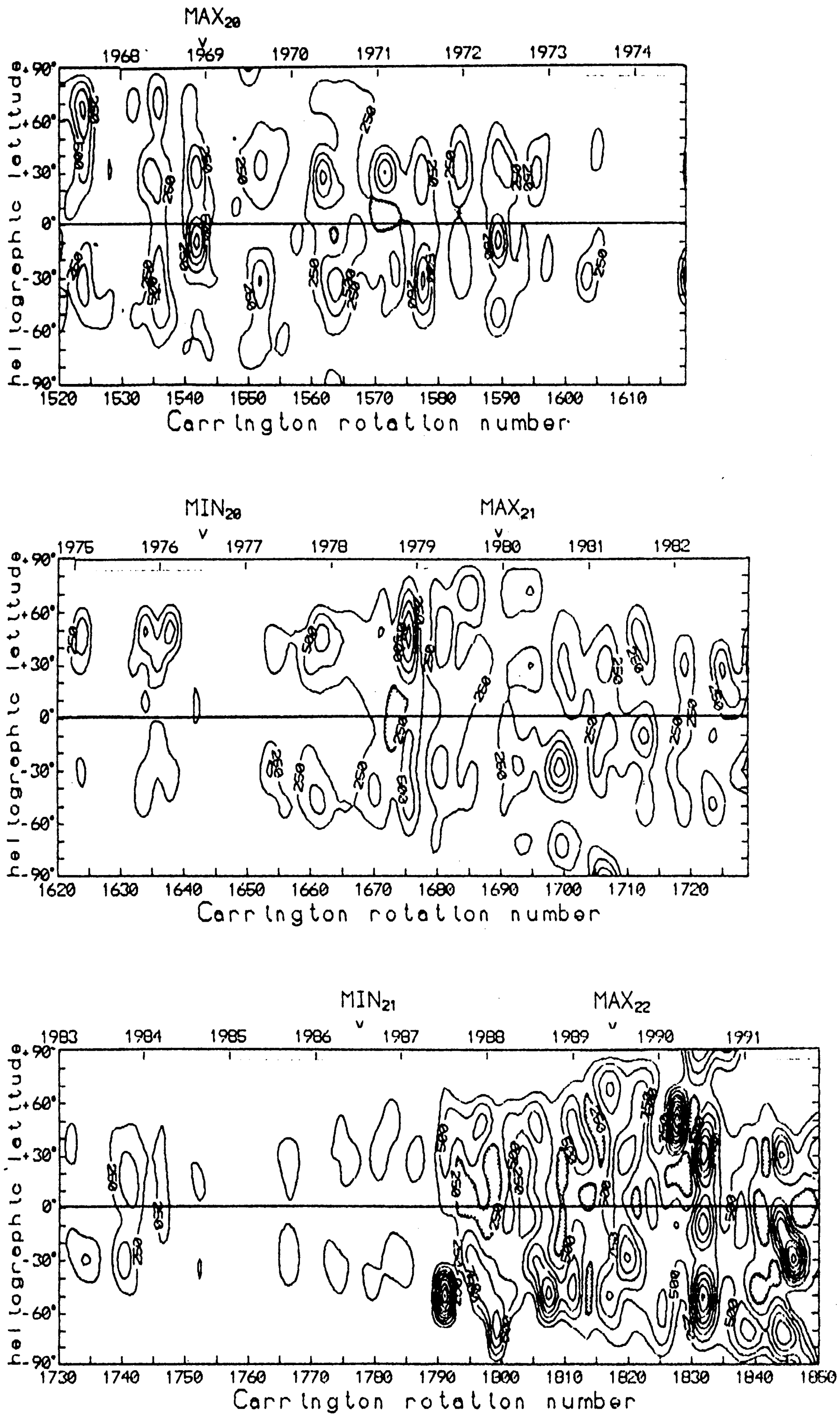

Figure 2. Time-latitudinal distribution of prominence areas for the years 1967-1991. Prominence area has been computed in the same manner as prominence numbers (see Figure 1). The minimum contour level shown is 250 units per grid cell (1 unit = degree × arcsec). The contour interval is 250 units.

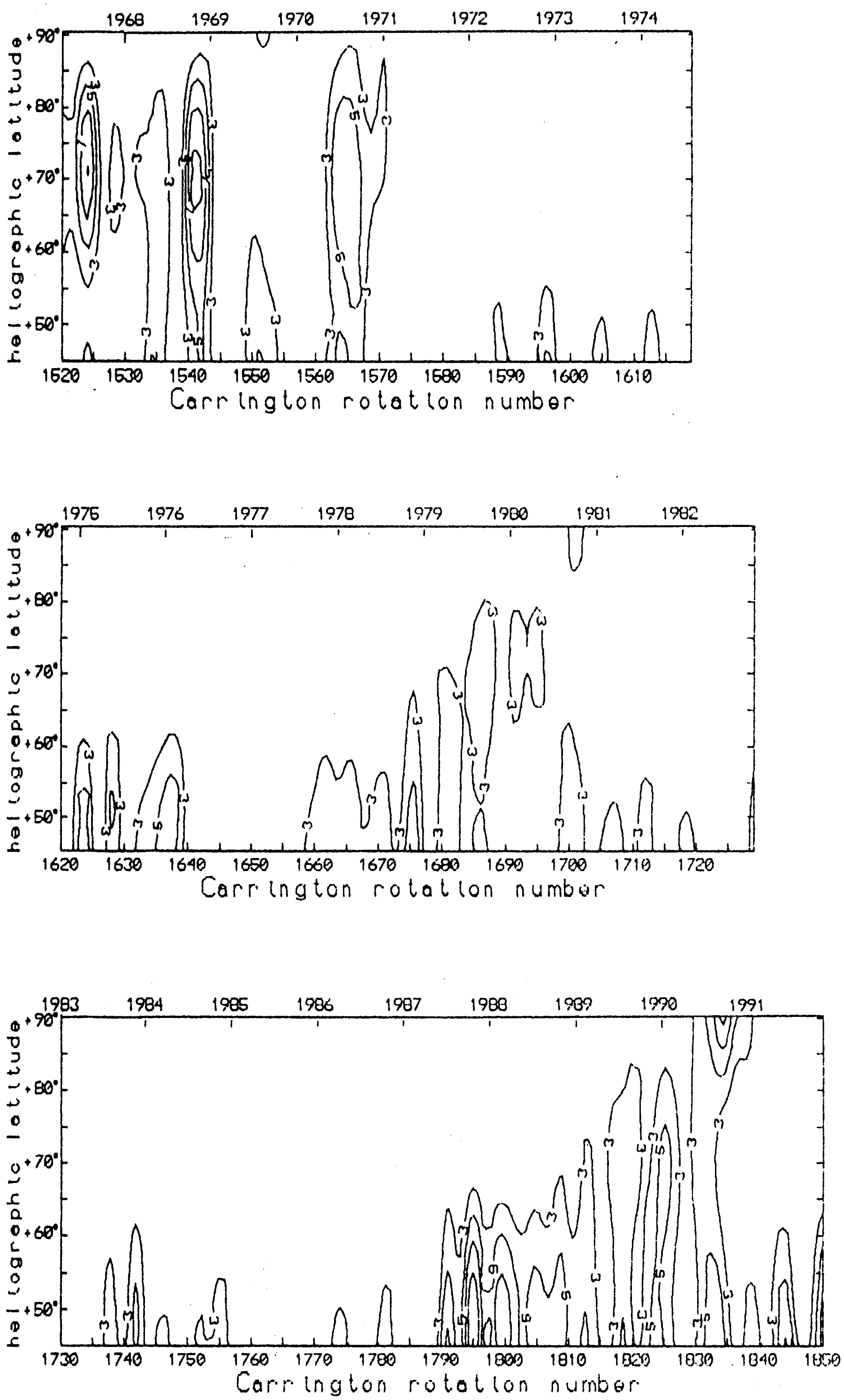

Figure 3. The same as in Figure 1 but for the northern (b> +45°) polar region only

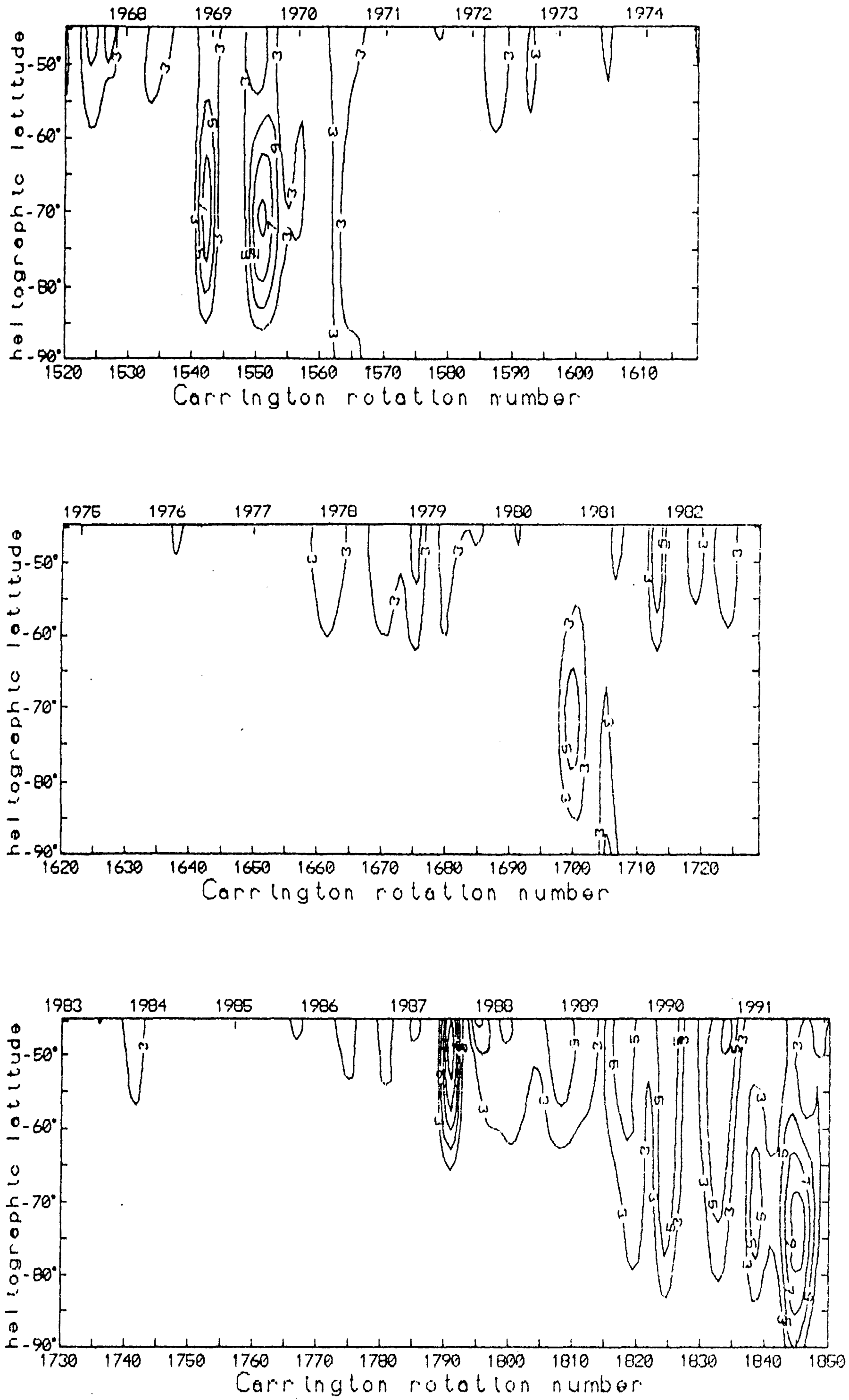

Figure 4. The same as in Figure 1 but only for the southern (b < -45°) polar region

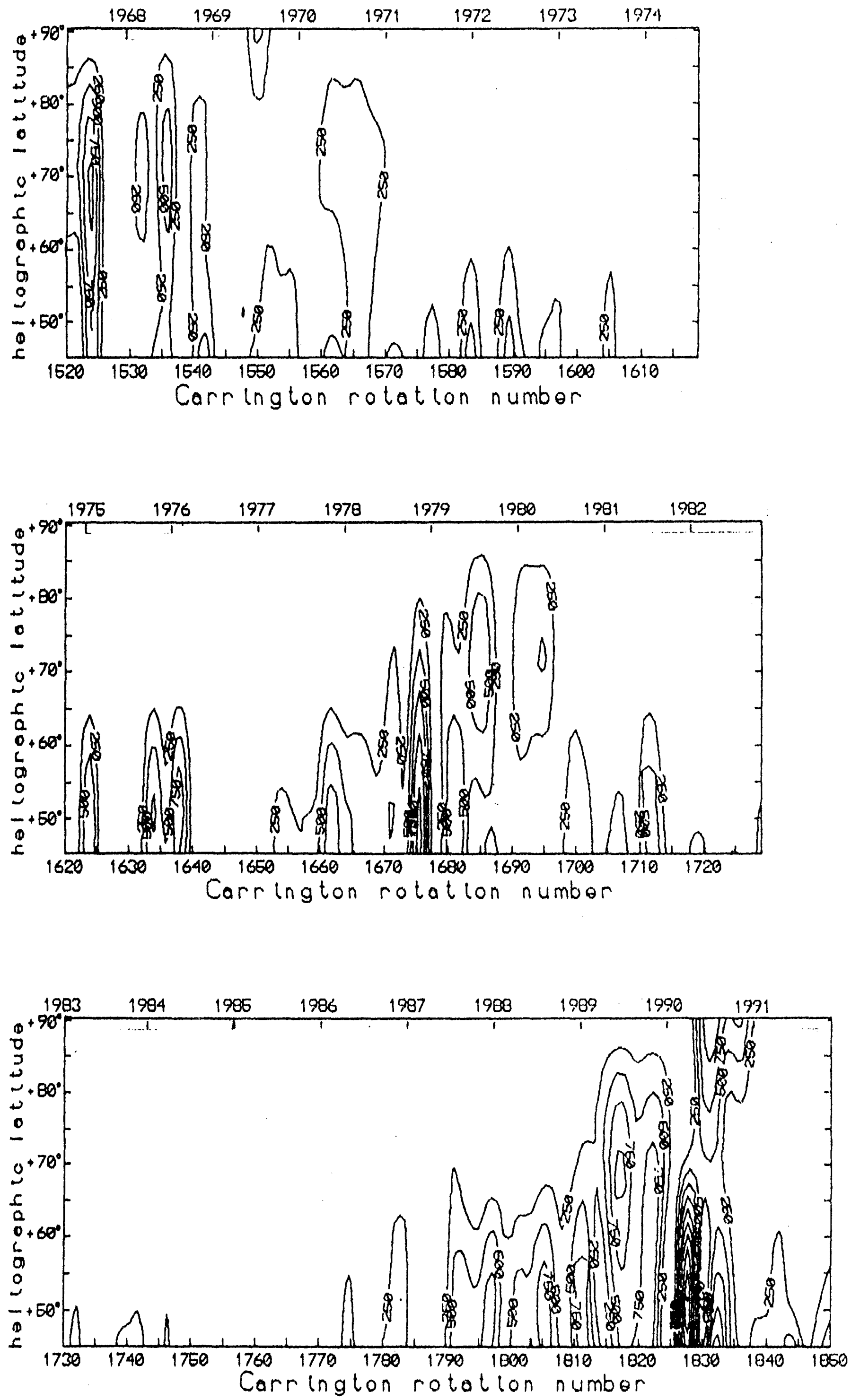

Figure 5. The same as in Figure 2 but only for the northern (b > +45°) polar region

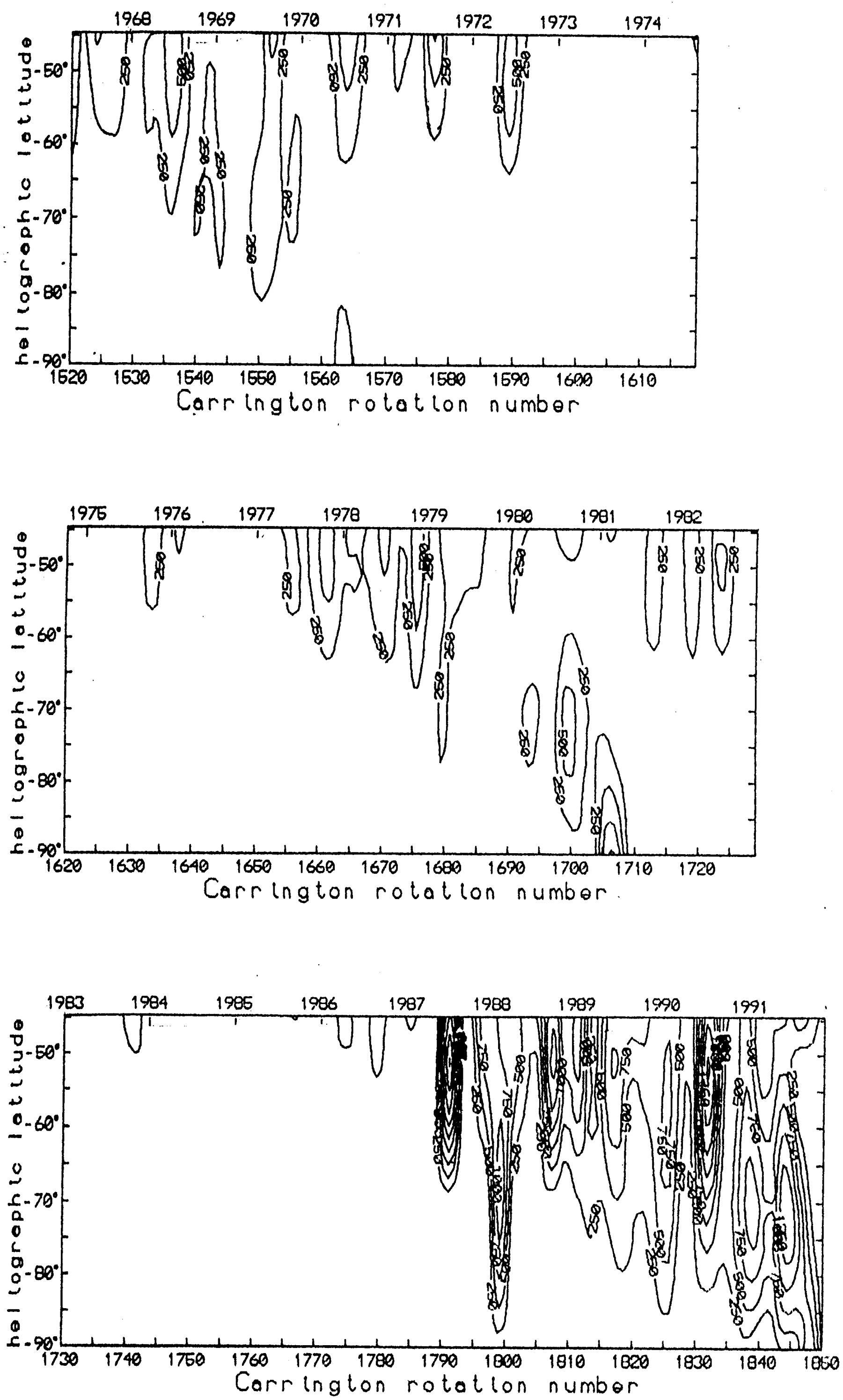

Figure 6. The same as in Figure 2 but only for the southern (b < -45°) polar region

of sunspot maximum (between rotations 1565 and 1570). The interval between these two branches is 20-25 rotations (of about 1.7 year).

The structure of the southern polar zone during the ascending phase of cycle 22 shows more than two branches, but they are not as pronounced. They can be seen in Figure 6, where the time-latitudinal distribution of prominence areas is shown. The first branch appears at rotation 1775 (in the epoch of the solar cycle minimum) and reaches the pole at rotation 1800, long before the sunspot maximum. The second branch forms at rotation 1805 and reaches the pole very soon at rotation 1820, just before the sunspot maximum. Shortly afterwards, around rotation 1830, another branch forms and moves rapidly to the pole.

Since the change of polarity of the solar magnetic field occurs when the prominence polar zone reaches the circumpolar regions, we suppose that the double or multiple structure of the prominence polar zone is closely correlated with the threefold reversals of the high-latitudinal magnetic field. This phenomenon has been explained quite recently by Benevolenskaya (1990) as the result of interaction of a low-frequency component (with a period of 20 years), describing a mean cyclic background field, and a high-frequency component (with a period of 1.7 to 2.5 years) with a slowly varying phase. We note that red coronal line intensities over cycle 20, nearly at all heliographic latitudes, shown nearly the same periods (Rušin et al. 1988). Quasi-bienal variations are observed in many solar activity features, or in geoactivity effects e.g.Djurovič and Stojič (1985).

Our results, as well as the results obtained by Waldmeier (1973), show that he secondary polar zone of prominences follows the first one with a delay of 1.5 to 2.5 years which is very close to the period of magnetic reversals.

It is also interesting to note that threefold reversals in the southern hemisphere were observed during the maximum of sunspot cycle 14.

5. Conclusion

The feature, the second polar branch or zone of prominence distribution, in the ascending phase of the solar cycle is not characteristic for each cycle and each hemisphere. Its formation probably reflects the appearance of a high frequency component of the background high-latitude magnetic field during the ending phase of the extended solar cycle.

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