NORTH-SOUTH ASYMMETRY IN SUDDEN DISAPPEARANCES OF SOLAR PROMINENCES

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Abstract. This paper presents the results of a study of the N–S asymmetry in sudden disappearances (SD) of solar prominences during solar cycles 18–21, obtained as a part of a more extensive research on SD and reappearances during years 1931–1985 (Ballester, 1984). As can be seen, the N–S SD asymmetry curve is not in phase with the solar cycle and peaks about the time of solar minimum, the asymmetry reverses in sign during the solar maximum, being, this change of sign, coincident with the reversal of the Sun's magnetic dipole. The SD asymmetry curve can be fitted by a sinusoidal function with a period of eleven years. On the other hand, the SD asymmetry curve shows a strong coincidence with the N–S asymmetries presented by other solar activity manifestations as studied by different authors.

1. Introduction

N–S and E–W asymmetries of several manifestations of solar activity have been studied, in the past, by different authors. Taking into account only the N–S asymmetry studies, Waldmeier (1971) used different features of solar activity to study its N–S asymmetry during the interval 1959–1969, and pointed out a strong asymmetry that favours the northern hemisphere, only the coronal line 6374 Å runs completely different showing an opposite behaviour. Besides, Waldmeier (1971) argues that the asymmetry is not or not directly connected with the solar cycle, it seems, however, that it has a longer period, approximately, 80–100 years. Hansen and Hansen (1975) studied the global distribution of solar filaments during solar cycle 20 looking for changes in the general topology of photospheric magnetic fields. They concluded that there is, during part of the cycle, a great preponderance of filaments in the northern hemisphere which evidences an asymmetry in solar activity. Roy (1977), using major solar flares, pointed out an asymmetry, favouring northern hemisphere, during 1958–1970 and notes that the asymmetry does not appear to be connected with the solar cycle. Yadav *et al.* (1980) studied the N–S asymmetry of solar flares of different importances during the years 1957–1978 obtaining that the number of flares is large in the northern hemisphere during the period 1957–1970, but after 1970 this behaviour reverses. They also found that the number of flares is greater in the hemisphere where the Sun's general magnetic field is negative and that during the intervals 1957–1958 and 1969–1971 when the Sun's general magnetic field has reversed the N–S asymmetry had also been reversed. Knoška (1985) studied the N–S and E–W asymmetry of flare activity during the years 1937–1978 using the flare index (q) introduced by Kleczek (1952, 1953), for the interval studied no unique relationship was found between the asymmetry of flare activity and the eleven year solar cycle. Swinson *et al.* (1986a), looking for long-term variation in the N–S asymmetry of solar activity, studied 110 years of sunspot numbers and found that, in general,

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northern hemisphere activity peaks about two years after sunspot minimum and that this peak is greater during even cycles, suggesting a 22-yr periodicity in N–S asymmetry of solar activity. Taking all this into account, our aim here has been to perform a study of the N–S asymmetry in SD of solar prominences, during solar cycles 18–21, looking for the existence of the asymmetry, the behaviour of this asymmetry, the possible connection with solar cycle, and the existence of a periodicity in the asymmetry.

2. N–S Asymmetry in Sudden Disappearances

To study the N–S Asymmetry in SD of solar prominences about 3000 data on SD during years 1931–1985 were collected from *Cartes Synoptiques de la Chromosphere Solaire*.

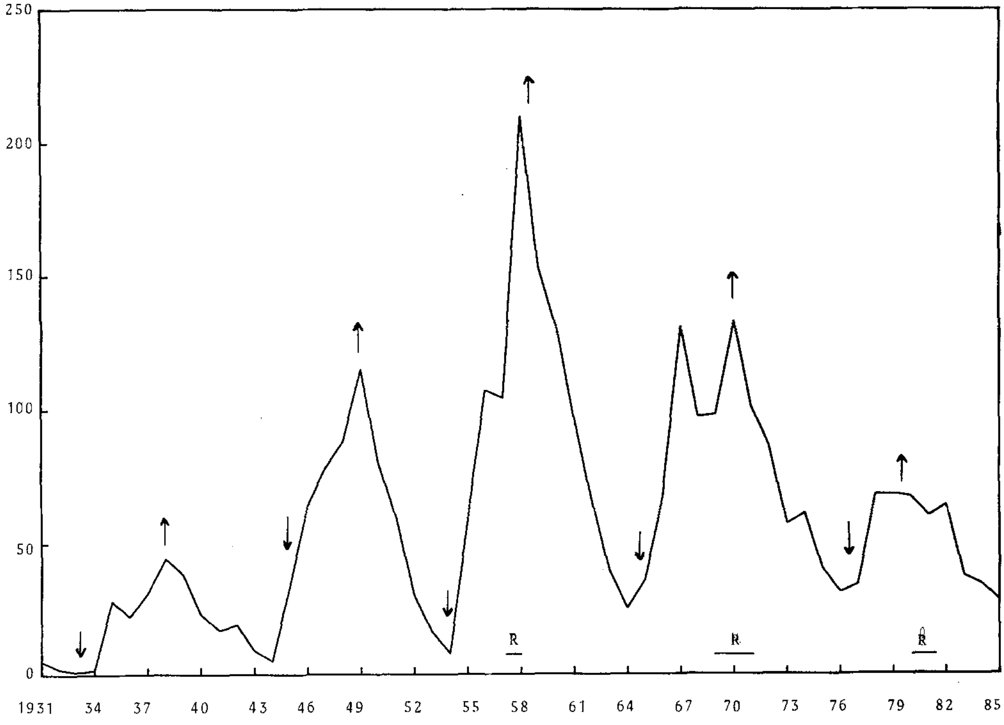

Fig. 1. Number of sudden disappearances versus year (1931–1985). Downward arrows indicate solar activity minima, upward arrow indicate solar activity maxima, and *R* indicate the epoch of the reversals of the Sun's magnetic dipole.

Figure 1 shows the shape of the curve representing the number of SD versus years, and as can be seen, the number of SD rises as the maximum of solar activity is reached and decreases with the decay of activity, reflecting the solar cycle. We define the SD asymmetry between hemispheres as

$$AS = (SD_n - SD_s)/(SD_n + SD_s),$$

TABLE I

The asymmetry in sudden disappearances of solar prominences

Year	AS	Year	AS	Year	AS	Year	AS
1931	1	1945	−0.27	1959	−0.013	1973	−0.12
1932	−1	1946	0.19	1960	0.056	1974	−0.37
1933	1	1947	0.012	1961	0.12	1975	0.2
1934	−1	1948	−0.2	1962	0.14	1976	−0.096
1935	−0.36	1949	0.05	1963	0.33	1977	0.58
1936	−0.33	1950	0.26	1964	0.76	1978	−0.12
1937	−0.032	1951	0.06	1965	0.72	1979	0.187
1938	0.045	1952	0.38	1966	0.85	1980	0.06
1939	−0.1	1953	0.125	1967	0.3	1981	−0.05
1940	−0.21	1954	0.75	1968	0.2	1982	−0.09
1941	−0.06	1955	0.45	1969	0.16	1983	−0.62
1942	0	1956	0.43	1970	0.14	1984	0.0
1943	0.11	1957	0.23	1971	−0.04	1985	−0.5
1944	−1	1958	0.03	1972	−0.15		

where SD_n, SD_s means the number of SD in each hemisphere, respectively; then, for $AS > 0$ the activity in northern hemisphere dominates and for $AS < 0$, the opposite happens. The value of AS for these years is presented in Table I and it may be observed that during the years 1931–1946 the asymmetry suffers strange and strong variations taking, sometimes, the value 1 or −1. For this reason, we have not considered these data, assuming they are due to misobservations of the Sun during that period of time and, accordingly, only the values of the asymmetry for the years 1947–1985 are taken into account, covering cycles 19, 20, and the major part of 18 and 21. The behaviour of the N–S SD asymmetry during these years can be seen in Figure 2. The shape of the curve indicates that the peaks of the asymmetry (years 1954, 1966, 1974, 1977, 1982) never coincide with the maximum of solar activity, the asymmetry has peaked, at minimum of solar activity, in 1954 and around the minimum in 1966, 1974, 1977, also, we can see that during the maximum (1947–1948, 1958–1959, 1970–1971, 1980–1981) there is a reversal in the sign of the asymmetry, coincident with the reversal of the Sun's general magnetic field in 1957–1958, 1969–1971 (Yadav *et al.*, 1980) and with the last reversal in 1980–1981 (DeVore and Sheeley, 1987). It seems, however, that when the asymmetry changes from positive to negative the asymmetry shows a tendency to recover very quickly (1948–1949, 1959–1960, 1976–1977, 1978–1979) the positive value.

On the other hand, we have looked for a periodicity in the SD asymmetry curve trying to fit the data to a sinusoidal function of the form

$$AS = C + A \sin w(t - t_0)$$

with a constant term C, the amplitude A, and $t_0 = 1947$; the frequency was fixed at a value corresponding to an eleven years period. The resulting constant term and the wave amplitude were 0.157 and −0.26 with the wave having a maximum positive value in the

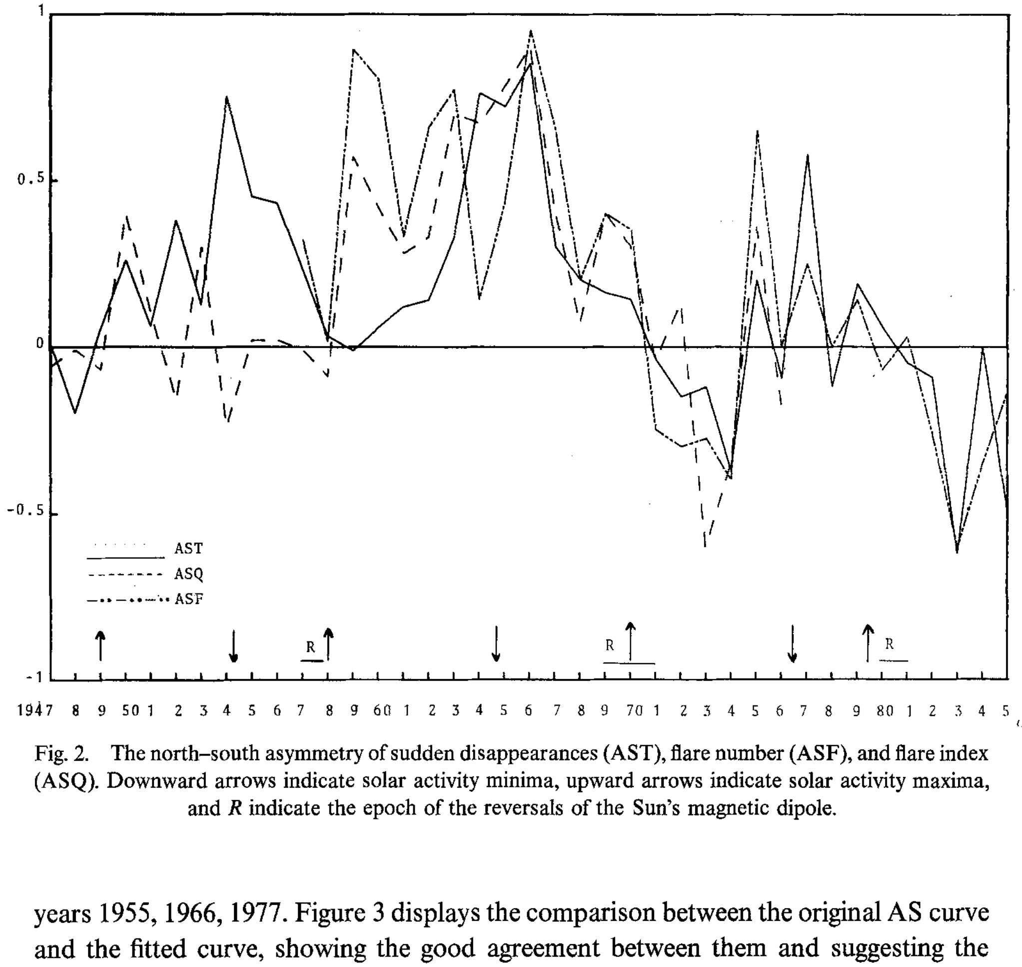

Fig. 2. The north–south asymmetry of sudden disappearances (AST), flare number (ASF), and flare index (ASQ). Downward arrows indicate solar activity minima, upward arrows indicate solar activity maxima, and R indicate the epoch of the reversals of the Sun's magnetic dipole.

years 1955, 1966, 1977. Figure 3 displays the comparison between the original AS curve and the fitted curve, showing the good agreement between them and suggesting the possibility that the N–S SD asymmetry have a periodic behaviour shifted in phase with respect to the solar cycle. Figure 4 shows the data about sunspots, faculae, and equatorial prominence areas used by Waldmeier (1971). The prominence area curve has a minimum in 1959 and a maximum in 1966 in agreement exactly with the behaviour of our results; instead, the sunspot numbers and faculae areas show the opposite behaviour in 1959 and the same in 1966. We have determined the flare number asymmetry during years 1957–1985, using the flare data in *Solar Geophysical Data*, by means of the expression

$$\mathrm{ASF} = (F_n - F_s)/(F_n + F_s)\,,$$

where F_n and F_s are the number of flares in northern and southern hemispheres, respectively, the results have been plotted in Figure 2. Besides, the asymmetry of the flare index (q), introduced by Kleczek (1952, 1953), and defined as

$$q = it\,,$$

where i is the importance of the flare and t duration in minutes, has been calculated by

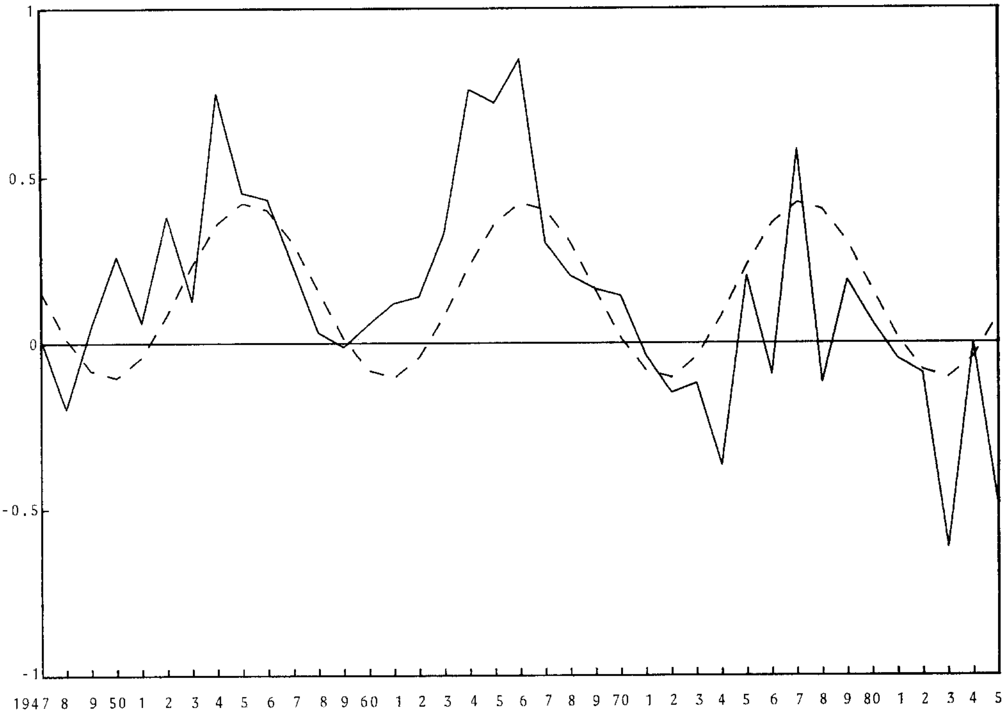

Fig. 3. The north–south asymmetry of sudden disappearances and the fitted sinusoidal curve with a period of eleven years.

Knoška (1985) in the form

$$ASQ = (q_n - q_s)/(q_n + q_s),$$

and the results have also been plotted in Figure 2. It can be observed that the shape of these two last curves strongly agrees with the SD asymmetry curve with two exceptions, in 1959 where, curiously, are in agreement with the results of N–S asymmetry for sunspots and faculae areas of Waldmeier (1971), and in 1964 for the flare number asymmetry. The general coincidence in the shape of the asymmetry curves for the different manifestations of solar activity suggest that this phenomenon of the N–S asymmetry is a typical feature of solar activity showing, for example, a strong correlation with the south pointing density gradient in cosmic-ray intensity perpendicular to the ecliptic plane during years 1959–1970, when the activity in the northern hemisphere was more important (Swinson *et al.*, 1986b).

3. Conclusions

The analysis of the N–S asymmetry curve over the 39-yr period 1947–1985 leads to the following conclusions:

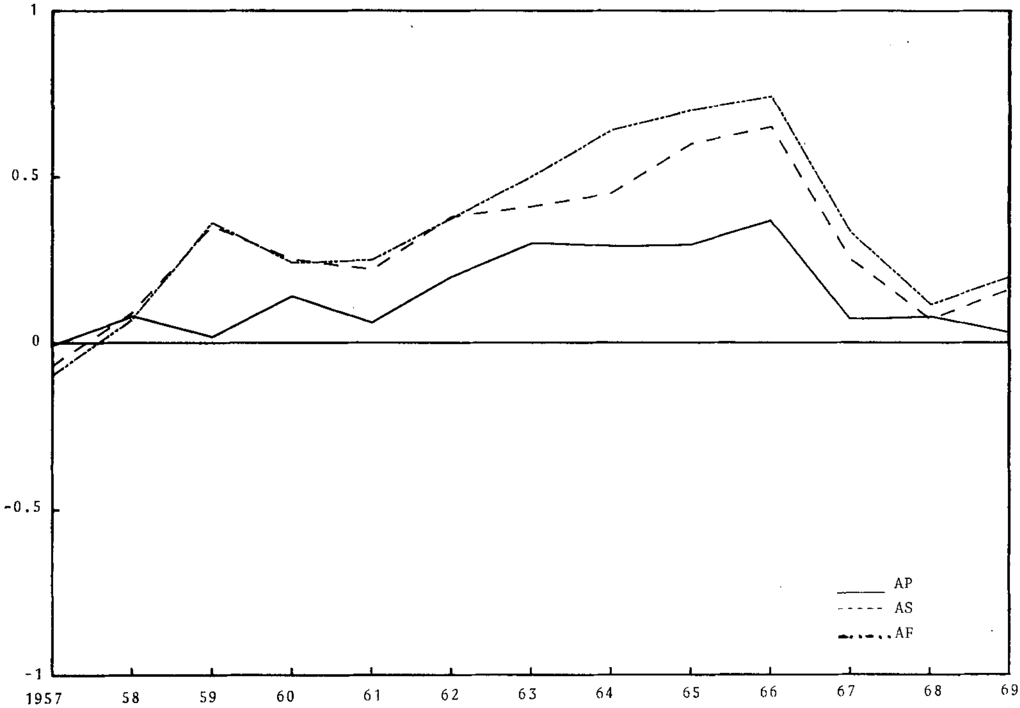

Fig. 4. The north–south asymmetry of equatorial prominence areas (AP), sunspots numbers (AS), and faculae areas (AF). (Adapted from Waldmeier, 1971.)

(1) The asymmetry curve is not in phase with the solar cycle and peaks at or around the minimum of solar activity.

(2) Always, for the considered period of time, the sign of the asymmetry changed, from positive to negative, during the solar maximum at the time of the reversal of the Sun's magnetic dipole, recovering, most times quickly, the positive value.

(3) It has been possible to fit the N–S SD asymmetry curve to a sinusoidal function of the form $AS = C + A \sin w(t - t_0)$ with a period of eleven years. The curve reflects in a correct way the behaviour of the N–S asymmetry during the period of time considered.

(4) There is a good agreement between the N–S asymmetry curves obtained, for different manifestations of the solar activity, by different authors and the results presented here, suggesting that the behaviour of N–S asymmetry of solar activity is the same whatever be the manifestation being considered.

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