

# THE NORTH–SOUTH ASYMMETRY OF SOFT X-RAY SOLAR FLARES

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*Abstract.* We analyse the North-South (N-S) asymmetry of soft X-ray (SXR) solar flares during the 11-year solar cycle (SC). After reviewing the literature on flare dominance in the northern and southern hemispheres of the solar disk for SCs 17–23, we analyse the SXR flare distribution in the two hemispheres during the period 1976–2001. The analysis was made using the number of flares ( $N$ ) and the  $Q_x$  index, which evaluates the energy emitted by flares in soft X-ray. The monthly and annual N-S asymmetry values computed by us for the mentioned period are in agreement with the results from the literature. The degree of the N-S asymmetry for both  $N$  and  $Q_x$  indices confirmed the antiphase of SXR flare emergence for spectral classes M and X, and class C, respectively, noted by Mariș et al. (2000). Finally, we consider that the detailed study of the descending and minimum phases of the SCs, at the stage when magnetic phenomena from both the old and the new cycle interact in the solar atmosphere, would be useful for inferring information about the activity level of the next cycle.

*Key words:* Sun – solar flares – soft X-ray – N-S asymmetry.

## 1. INTRODUCTION

Long-term observations of active solar phenomena indicate that their occurrence in the northern and southern (as well as eastern and western) hemispheres of the solar disk is not uniform, with more events occurring in one or other hemisphere during certain periods of time. This phenomenon is referred to as asymmetry.

Much work was devoted to the study of this subject, beginning with Maunder (1904), who observed the N-S asymmetry of sunspots during the period 1874–1902. Even if many authors paid particular attention to the asymmetry of the photospheric features (sunspot relative number, sunspot area, magnetic classes of sunspots, etc.) and their relation to the phase of the 11-year solar cycle (SC), attention was also paid to the asymmetry of all solar activity features from the entire solar atmosphere. Photospheric magnetic fields, facula, sudden disappearing filaments, (active) prominences, white-light flares, soft X-ray and H $\alpha$  flares, gamma-ray and hard X-ray burst sources, the sources of outstanding events in radio band (radio bursts – RB), coronal mass ejections, coronal holes, different coronal indices and solar wind parameters representing the solar indices investigated (see, e.g., Li et al., 2002 and references therein).

Some of the authors (e.g., Carbonell et al., 1993; Li et al., 1998; Ataç and Özgüç, 2001) demonstrated that the N-S asymmetry has high statistical significance. This means that the found non-uniformity is a real feature of the solar activity, and cannot be due to random fluctuations generated from a binomial or uniform distribution of probability between hemispheres.

Other authors tried to find a periodicity in this distribution. First, an 11–12-year periodicity was inferred, but whether or not it is related to the classical sunspot cycle is still controversial. Most of them concluded, nevertheless, that the asymmetry is not in phase with the 11-year SC (see, e.g., Garcia, 1990; Vizoso and Ballester, 1990; Temmer et al., 2001). Longer-term periods were also suggested: 8 SCs (Vizoso and Ballester, 1990; Ataç and Özgüç, 1996) and even 12 SCs (Verma, 1992; Li et al., 2002). Based on such studies the asymmetry of the solar activity in the present SC (No. 23) should favour the southern hemisphere; but current data suggest otherwise (see Sections 3 and 4).

In the present paper we investigate the N-S asymmetry of soft X-ray (SXR) flares during the period 1976–2001 comprising three solar cycles, Nos 21–23. We begin by reviewing all N-S flare asymmetry research to date, from its historic beginnings to modern state-of-the-art research in this field (Section 2). We then present both our data analysis techniques and subsequent results. Our approach consisted of examining the number of events, as well as studying the SXR flare index,  $Q_x$  (Section 3). The monthly and annual distributions of both, in the northern and southern hemispheres, as well as on the entire solar disk are discussed in Section 4. The N-S asymmetry of the  $Q_x$  index is also evaluated at different phases of solar cycles. Our concluding remarks are put forward in Section 5.

## 2. THE FLARE DISTRIBUTION FOR THE LAST SEVEN SOLAR CYCLES

Generally, flares follow the solar cycle evolution with their power and

frequency of occurrence increasing towards its maximum of activity. Concerning their heliospheric distribution throughout the cycles, the same behaviour as seen in all other solar phenomena can be inferred.

We reviewed previous studies related to the flare N-S asymmetry starting with the first continuous monitoring of such events in 1936. Roy (1977) presented some results dating back to 1859; but as he used the white light flare number, his report consists of only nine events for a period of 96 years (1859–1954), therefore, we restrict our references to those since the first regular flare observations were made. We gathered a collection of data covering a period of 64 years, which allows a reconstruction of the N-S asymmetry for almost seven SCs. We give references for the available N-S asymmetry data and, for every cycle, the results and different approaches of several more authors are provided.

A summary of the hemispheric dominance for the flare occurrence during each SC considered is given in Table 1. One can easily see that even if the authors used different indices in their analysis, the results would be the same for a given SC. There is, however, one exception (SC 21) in which we came across different results: two papers reported zero asymmetry for this cycle, while another six revealed a southern dominance. Nevertheless, it seems that the ambiguity is due to the very small value of the asymmetry in the southern hemisphere (51 % for SXR flares and 50.6 % for H $\alpha$  flares, as reported by Temmer et al., 2001, 2002).

Table 1

The flare dominance over one of the solar hemispheres for SCs 17–23

Cycle	Hemisphere	Author(s)	Index	Period
1	2	3	4	5
17	North	Bell (1961)	Major flares	1937-1944
		Knoska (1985)	Flare index	1936-1944
		Verma (1993)	H $\alpha$ flares	1936-1944
		Ataç & Özgüç (1996)	Flare index	1936-1944
18	North	Bell (1961)	Major flares	1945-1955
		Knoska (1985)	Flare index	1944-1955
		Verma (1993)	H $\alpha$ flares	1945-1955
		Ataç & Özgüç (1996)	Flare index	1944-1954
19	North	Reid (1968)	H $\alpha$ flares	1958-1965
		Popovici & Mariş (1968)	H $\alpha$ fl. with geophys. effects	1955-1965
		Mariş & Dinulescu (1969)	H $\alpha$ fl. with geophys. effects	1956-1963
		Yadav et al. (1980)	H $\alpha$ flares	1957-1965
		Knoska (1985)	Flare index	1955-1965
		Verma et al. (1987)	Major flares	1955-1965
		Bai (1990)	Major flares	1955-1964
		Ataç & Özgüç (1996)	Flare index	1954-1964

1	2	3	4	5
20	North	Roy (1977)	Major flares	1962-1974
		Yadav et al. (1980)	H $\alpha$ flares	1965-1978
		Knoska (1985)	Flare index	1965-1976
		Verma et al. (1987)	Major flares	1966-1976
		Bai (1990)	Major flares	1965-1975
		Garcia (1990)	Large flares	1969-1976
		Krivsky et al. (1991)	H $\alpha$ flares with type II RB	1965-1976
		Ataç & Özgüç (1996)	Flare index	1964-1975
21	South	Verma (1987)	White light flares	1976-1986
		Dinulescu & Dinulescu (1991)	H $\alpha$ flares	1976-1986
		Mariş & Tifrea (1994)	H $\alpha$ flares with types II+IV RB	1976-1986
		Ataç & Özgüç (1996)	Flare index	1976-1985
		Temmer et al. (2001)	H $\alpha$ flares	1976-1986
		Temmer et al. (2002)	Soft X-ray flares	1975-1986
	Equal	Bai (1990)	Major flares	1976-1986
		Garcia (1990)	Large flares	1977-1988
22	South	Bai (1990)	Major flares	1986-1996
		Verma (1993)	H $\alpha$ flares	1987-1990
		Ataç & Özgüç (1996)	Flare index	1986-1994
		Li et al. (1998)	Soft X-ray flares	1987-1992
		Temmer et al. (2001)	H $\alpha$ flares	1987-1996
		Temmer et al. (2002)	Soft X-ray flares	1987-1996
23	North	Ataç & Özgüç (2001)	Flare index	1996-1999
		Temmer et al. (2001)	H $\alpha$ flares	1997-1999
		Temmer et al. (2002)	Soft X-ray flares	1997-2000

The studies of flare asymmetry were made on several types of indices. The "numbers of flares" (total number of flares, number of major flares, number of flare sources of some radio bursts, number of flares with geophysical effects) appearing in a single solar hemisphere were often used. This index reflects how frequently solar flares appear in one solar hemisphere and give little information about the associated energy release. Its main time variation is the 11-year cycle. Other types of indices, which contain more information on the importance of these phenomena are also used to evaluate the energy released by flares (Knoska, 1985; Mariş, 1987; Ataç and Özgüç, 1996; 2001). Such indices prove more useful in the analysis of the flare spatial flare distribution, and reveal flare concentrations in active longitudes or in one solar hemisphere (N or S, e.g., N-S asymmetry). In fact, there are two different classes of indices: frequency indices and importance indices (Kuklin, 1976). The spatial distribution of the importance indices is less influenced by the differential rotation. This statement is in good accordance with the hypothesis concerning the deep anchorage in the convection zone of the active regions producing flares of great importance (Garcia, 1990).

### 3. DATA AND METHOD OF ANALYSIS

Generally, for a given characteristic  $C$ , separately determined in both solar hemispheres, one can calculate two almost equivalent asymmetry indices:

$$a = \frac{C_N}{C_S} \text{ and } A = \frac{C_N - C_S}{C_N + C_S} \quad (1)$$

We have chosen the  $A$  index for our studies of flare asymmetry.

In this paper we analyse the asymmetrical behaviour of SXR flares during the last three SCs (the period 1976–2001), using two indices: the SXR flare number ( $N$ ) and the  $Q_x$  index. The latter evaluates the energy emitted by flares in the 1–8 Å range, while the former expresses the frequency of spectral classes B, C, M and X flares, according them the same weight but does not give any information about the energy of the event. Data used in this study were provided by WDC-A for Solar-Terrestrial Physics, NOAA.

In evaluating the energy of SXR flares, we averaged the total energy emitted in the 1–8 Å range over a period of 24 hours (Mariş et al., 2002a; 2002b). Thus, we define an index  $Q_x$  by:

$$Q_x = i_x \times t, \quad (2)$$

where  $i_x$  is the intensity scale of the importance of X-ray flare spectral class and  $t$  is the duration of the flare in minutes. To obtain final daily values, the daily sums of the index for all SXR flares are divided by the sums of total flare duration for that day. We defined  $i_x$ , as in Table 2, based on the classification of solar flares according to the magnitude order of the peak burst intensity, measured from Earth-orbit within 1–8 Å.

Table 2

The  $i_x$  coefficient values for the different spectral classes of X-ray flares

X-ray class	$i_x$
B	0.5
1.1-5.0 C	1.0
5.1-9.9 C	1.5
1.1-5.0 M	2.0
5.1-9.9 M	2.5
1.1-5.0 X	3.0
5.1-9.9 X	3.5

This evaluation mentioned above is similar to that carried out on H $\alpha$  flares

energy release. Many authors used the index  $Q$  introduced by Kleczek, (1952) for describing the H $\alpha$  flare activity over a 24 hours period. There is a difference between the indices derived from the two different kinds of flare classification: the  $Q$  index is defined using the area covered by flares in H $\alpha$ , while the  $Q_x$  index is defined using the energy emitted at the maximum phase in 1–8 Å, by SXR flares. However, we consider the  $Q_x$  index as a good indicator for the importance of X-ray flares, e.g. an importance index.

The histograms representing the monthly distributions of  $Q_x$  for both hemispheres and the entire solar disk are given in Fig. 1.

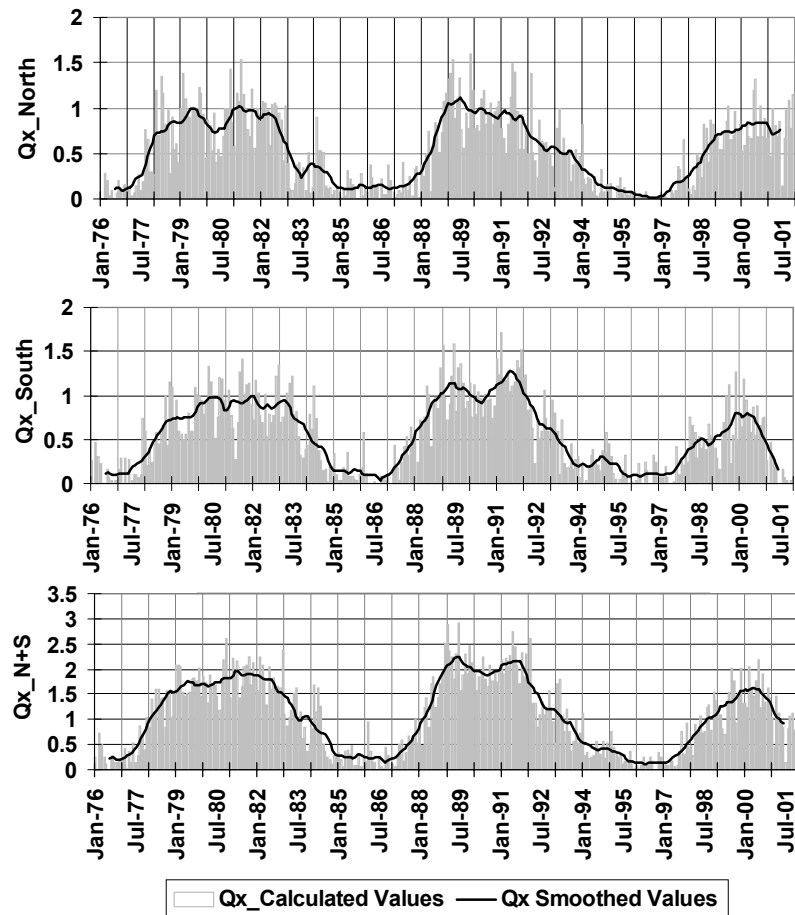


Fig. 1 – The monthly distributions of  $Q_x$  for: the northern hemisphere (upper panel), the southern hemisphere (middle panel) and, the entire disk (bottom panel).

For better inferring the cyclic aspect of the considered indices, we analysed their smoothed mean monthly values. The smoothing method is also used for the Wolf numbers in forecasting studies, because it eliminates the seasonal variations. The values are calculated according to:

$$Q_s = (Q_{i-6} + Q_{i+6} + 2\sum_{i-5}^{i+5} Q_j) / 24. \quad (3)$$

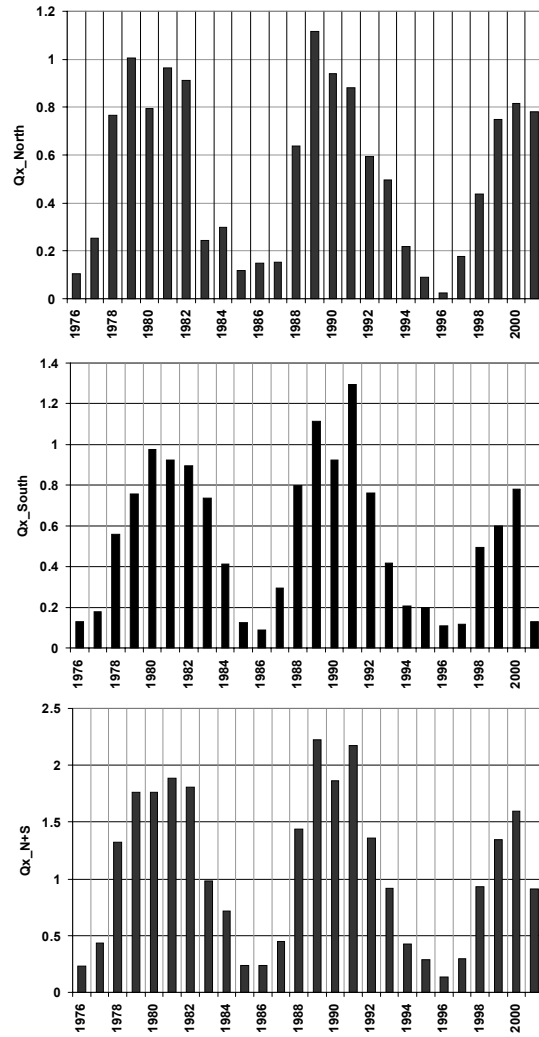


Fig. 2 – The annual distributions of  $Q_x$  for: the northern hemisphere (upper panel) the southern hemisphere (middle panel) and, the entire disk (bottom panel).

For a comparison between the smoothed monthly values of the  $Q_x$  index over the whole solar disk and the smoothed Wolf numbers, see Fig. 2 of Popescu et al. (2002). The smoothed monthly values of the  $Q_x$  index for the northern and southern hemispheres, as well as for the entire solar disk, are superimposed on their histograms in Fig. 1.

We also calculated the annual values of the  $Q_x$  index. The histograms for both hemispheres and the for entire solar disk are plotted in Fig. 2.

We evaluated the degree of N-S asymmetrical distribution for the SXR flares (classes B, C, M and X) using the index of type  $A$  (see (1)) defined for the number of SXR flares, as:

$$A_N = \frac{N_N - N_S}{N_N + N_S}, \quad (4)$$

where  $N_N$  and  $N_S$  represent the numbers of flares in the northern and southern solar hemispheres, respectively. The  $A_N$  values were calculated both monthly and annually. We evaluate the N-S asymmetry of SXR flares for the importance index  $Q_x$ , by the asymmetry index  $A_Q$ , defined as:

$$A_Q = \frac{Q_N - Q_S}{Q_N + Q_S}, \quad (5)$$

The monthly degree of flare asymmetry, described both by the  $A_N$  and the  $A_Q$  indices, is presented in Fig. 3 (upper and bottom panels, respectively). Fluctuations from month to month are present in Fig. 3; we superimposed the smoothed values of the  $A_N$  and the  $A_Q$  indices in order to mark out the trend of the asymmetry.

In Fig. 4 we evaluate the annual N-S asymmetry of the indices used,  $N$  and  $Q_x$ , with formulas (4) and (5), respectively.

#### 4. ANALYSIS OF N-S ASYMMETRY

The cyclic behaviour of the indices  $N$  and  $Q_x$  was presented in Mariş et al. (2000) and Mariş et al. (2002a, b). The 11-year cycle can be observed in any of the solar activity indices considered.

The characteristics of the cycle phases are only a little different, depending upon the indices used for the same phenomenon. Thus, for  $N$  and  $Q_x$  (Fig. 2 and Fig. 3, respectively in Mariş et al., 2002a), the maxima for the two indices coincide

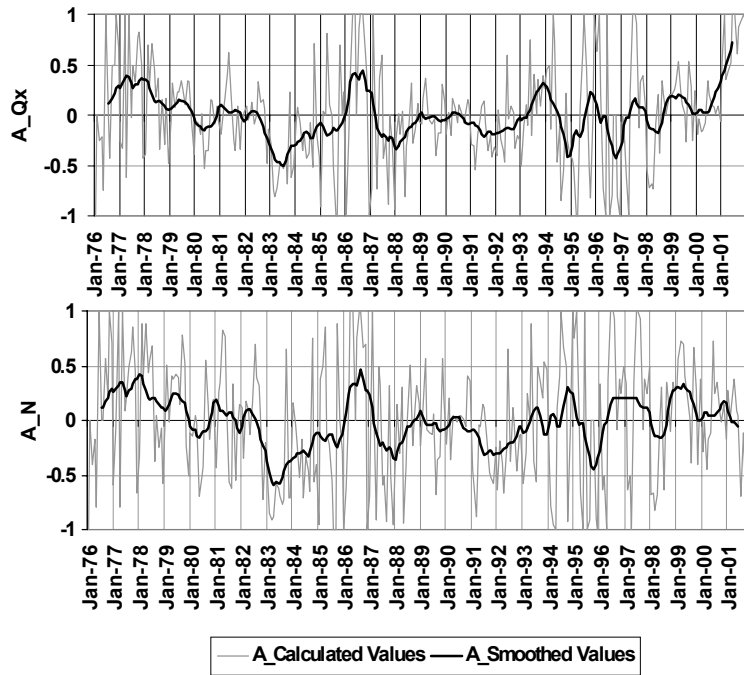


Fig. 3 – The monthly distribution of N-S asymmetry by the number of SXR flares,  $N$ , (bottom panel) and  $Q_x$  index (upper panel).

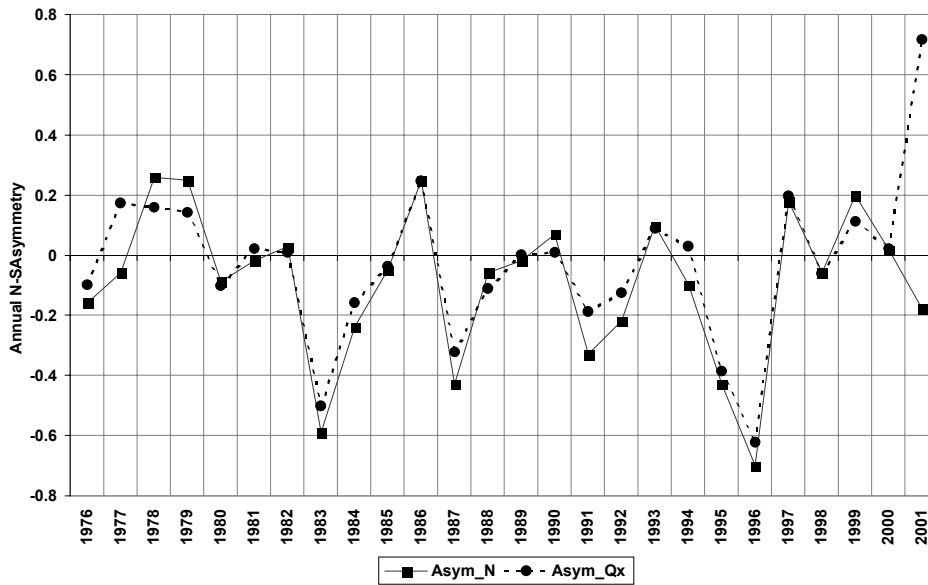


Fig. 4 – The annual N-S asymmetry of  $N$  and  $Q_x$  indices.

in time. If we compare the cycles of SXR flares to those of sunspots, we notice a delay of the flare maximum with respect to that of the sunspots.

#### 4.1. THE 11-YEAR CYCLE OF SXR FLARES IN N AND S HEMISPHERE

Fig. 1 emphasizes several differences between the cyclic behaviour of SXR flares in the two hemispheres. Thus, the activity of the SXR flares in the northern hemisphere (upper panel) has two maxima for SC 21 (placed approximately in May 1979 and March 1981, on the smoothed curve of  $Q_x$  values) and a single maximum for SC 22 (approximately in May 1989), followed by a prolonged period of intense activity of SXR flares until August 1991. A smaller value of the  $Q_x$  indices characterizes SC 23 with a relatively flat maximum stretching throughout two years, 1999 and 2000. There may be a second maximum but the data at our disposal are not sufficient to warrant further comment. On the descending slopes of SC 21 and SC 22, short "pulses" of increased activity could be observed in 1983–1984 and 1993–1994, respectively.

In the southern hemisphere (middle panel) the characteristics of the cycles are different from those observed in the northern hemisphere. Thus, in SC 21 the double maximum almost disappears, but the period of intense activity lasts for more than 3 years, from 1979 until the middle of 1982. SC 22 has two relatively equal maxima in the southern hemisphere, situated in May 1979 and May–July 1991 (on the smoothed curve), but here the intense activity is restricted to a period of less than 3 years. The characteristics of SC 23 in the South also differ from those in the North: a single, more pronounced and shorter maximum is found in the middle of 2000 and the tendency to return to intense activity (a secondary maximum) cannot be assumed. The pulses of activity on the descending slope are also present in the southern hemisphere, approximately in the same intervals, with slightly different intensities. The characteristics of SCs 21–23 according to the index  $Q_x$ , over the entire solar disk (bottom panel) preserve those of the two hemispheres, but seems to be determined by the activity of the SXR flares in the southern hemisphere. Thus, the structure of the  $Q_x$  cycle maxima for the entire solar disk is similar to the  $Q_x$  cycle maxima for the southern hemisphere alone. This structure reveals a flattened maximum for SC 21, a double maximum for SC 22 and a pronounced maximum for SC 23. The pulses of activity for SXR flares on the descending slope are also evident over the entire disk.

The annual values of the  $Q_x$  index in both hemispheres (Fig. 2) also indicate differences between the structures of the solar cycles in the North and in the South. Thus, in the North, SC 21 has a double maximum (1979 and 1981), but SCs 22 and

23 have single maxima, the 1989 activity being the most intense of the entire period analysed (upper panel). We notice the pulse of 1984, while the pulses on the descending slope of SC 22 in the monthly values of  $Q_x$  cannot be seen in the annual values. In the southern hemisphere, SC 21 no longer has a double maximum but it has a period of 3 years (1980–1982) of increased activity. SC 22 has two maxima (1989 and 1991) and the year 1995 can be considered an activity pulse (middle panel). The maximum of SC 23 can be found in 2000, after which the activity decreases suddenly. The annual  $Q_x$  values for the entire solar disk (bottom panel) emphasize the classical 11-year cycle, and reveal characteristics of both hemispheres as well as a southern dominance evident in the phases of the prolonged maximum of SC 21 and the double maximum of SC 22.

#### 4.2. THE DYNAMICS OF THE N-S ASYMMETRY DURING SCs 21–23

In Fig. 4 we notice the near identical variation of the N-S asymmetry for the two indices,  $N$  and  $Q_x$ , even if they have a different nature ( $N$  is a frequency, and  $Q_x$  is an importance index). A general trend can be inferred for the N-S asymmetry curve during a SC. At the beginning of a cycle, there is a preference for one of the hemispheres, while during, or immediately after the maximum epoch, the N-S asymmetry drops sharply towards zero and remains very low until the polarity reversal of the solar magnetic field. After this moment, in which a new dipole, with inverse polarities, is installed, the N-S asymmetry increases again, either in favour of the opposite hemisphere (for SC 21, it goes from North to South), or in favour of the same one (as for SC 22, where the southern hemisphere remains dominant). The current data of SC 23 does not allow us to yet infer which hemispheric preferences the flare activity will have on the descending phase of this cycle. Nevertheless, for the year 2001, the  $A_N$  and  $A_Q$  indices show that, even if in the southern hemisphere there were more SXR flares, the energy released by the northern ones was much greater.

A detailed examination of the N-S flare asymmetry is given in Fig. 3, where the monthly values of both our asymmetry indices are plotted. The smoothed value curve, printed in black above the monthly values, allows the inference of a variation tendency. For a clearer picture of the asymmetry indices, we present in Fig. 5 the smoothed values of the  $A_N$  and  $A_Q$  indices. The two curves evolve nearly identically until July 1993. During the interval July 1993 – July 1997, they present an antiphase evolution with short exceptions during the following periods: April–July 1994; April–July 1995; May–June 1996, which are strangely placed at one-year intervals. The inverse dynamics of the two indices is present again

between October 2000 – July 2001. These periods correspond to the descendent phase of SC 22 and to the maximum phase of SC 23, respectively.

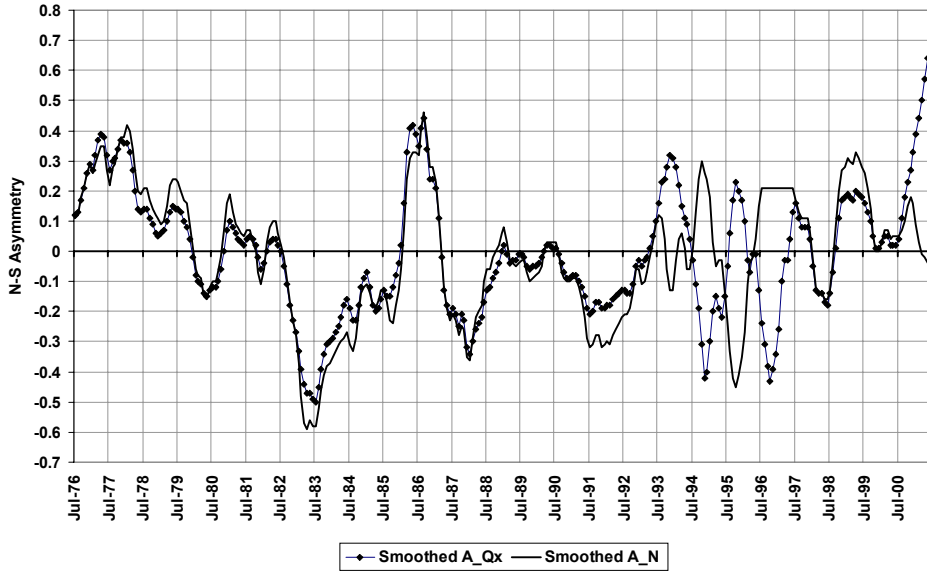


Fig. 5 – The smoothed curves of the N-S asymmetry for  $Q_x$  and  $N$  indices.

There is an explanation for the abnormal appearance of SC 23. During the years 2000–2001, a large number of very powerful SXR flares were registered, (e.g. the events of July 2000 and March–April 2001) as well as many small flares (C and B spectral classes). Mariș et al. (2002b) showed that during certain periods there is an alternation between the emergence of powerful SXR flares (X and M classes) and small importance flares (C class). When we calculated the daily  $Q_x$  index, we divided it by the total flare duration. Therefore, when there is a large number of C and B class flares, the value of the  $Q_x$  index could be small, whereas when there are even few M and X class flares the index values increases.

#### 4.3. THE STRENGTH OF N-S ASYMMETRY

In order to evaluate what the antiphase evolution of the two asymmetry indices can produce on the descending phase of SC 22, we try to estimate the strength of an entire cycle, on different phases and during some evident "pulses" of activity, through a mediated value,  $Q_{x,m}$ . These values were obtained by dividing

the sum of the  $Q_x$  indices by the number of months considered in each period, for three different intervals: the entire length (T) of the cycles, for the ascending phase (A) and the descending phase (D). For SC 23, instead of the total duration of the cycle, we took into consideration only the period available, 1996–2001, and we left out the descending phase. Our calculation used the minimum and maximum epochs of the considered cycles given by WDC–A for Solar-Terrestrial Physics, NOAA. For the phases of the SCs 21–23 we calculated the index  $Q_{x,m}$ , separately for the northern and southern hemispheres (Table 3). A similar estimate for the entire disk, which did not include the contribution of the B spectral class flares, was made by Popescu et al. (2002; Table 1 of that paper). One can notice a southern dominance for SCs 21 and 22 with the exception of the ascending phase of SC 21. All asymmetric values are relatively small irrespective of the cycle phase or the entire solar cycle.

Table 3

The values of the  $Q_{x,m}$  indices for the northern and southern hemispheres, during different phases of SCs 21–23

SC	Phase	Hemisphere	$Q_{x,m}$	$A, Q_{x,m}$
21	T / Jun 1976 – Aug 1986	North	0.49	– 0.01
		South	0.50	
	A / Jun 1976 – Nov 1979	North	0.59	+ 0.19
		South	0.40	
	D / Dec 1979 – Aug 1986	North	0.51	– 0.11
		South	0.63	
22	T / Sep 1986 – Sep 1996	North	0.52	– 0.07
		South	0.60	
	A / Sep 1986 – Jun 1989	North	0.52	– 0.07
		South	0.60	
	D / Jul 1989 – Sep 1996	North	0.51	– 0.09
		South	0.61	
23	Oct 1996 – Dec 2001	North	0.56	+ 0.15
		South	0.41	
	A / Oct 1996 – Mar 2000	North	0.43	+ 0.01
		South	0.42	

SC 21 had a northern hemispheric dominance for the ascending phase, which shifted to the South for the second part of the cycle. For the entire cycle, we found a very weak southern dominance, as did most of the authors listed in Table 1. For SC 22 our data show a southern preference, in agreement with the other authors. One should notice the constant values of the  $Q_{x,m}$  index in both hemispheres for both phases, and for the entire cycle. The main feature of SC 23 up to the year

2001 is a northern dominance of SXR flares, the same as for  $H_{\alpha}$  flares and the flare index (see Table 1).

We have also calculated  $Q_{x,m}$  for the maximum phases of the cycles, taking into consideration that they begin in the month when the activity exceeded by 50% the level reached during the previous one and end in the month when the activity decreases by approximately 50% and then continues to go down.

Thus, we note the obtained periods with M in Table 4. The  $Q_{x,m}$  value for the maximum phases of the solar cycles in both hemispheres shows the high energy level emitted by SXR flares in those periods, in comparison to the entire cycle or its ascending or descending phases alone. The N-S asymmetry during the maximum phase is almost zero, the value of the  $Q_{x,m}$  index being practically the same as it is for the entire cycle (see row T in Table 3 and rows M in Table 4).

Table 4

The values of the  $Q_{x,m}$  indices for the northern and southern hemispheres, during the maximum phases and the "pulses" on the descending phase for SCs 21 and 22

SC		Period	Hemisphere	$Q_{x,m}$	$A_{-}Q_{x,m}$		
21	M	Sep 1978 – Dec 1982	North	0.91	+ 0.01		
			South	0.89			
	Pulses	Mar–Oct 1983	North	0.28	– 0.50		
			South	0.84			
		Jan–Jun 1984	North	0.53	– 0.12		
			South	0.67			
22	M	Jun 1988 – Feb 1992	North	0.95	– 0.06		
			South	1.08			
	Pulses	Feb 1993 – Jun 1993	North	0.67	+ 0.03		
			South	0.63			
		Oct 1993 – Mar 1994	North	0.43	+ 0.28		
			South	0.24			
		Jun–Oct 1994	North	0.13	– 0.27		
			South	0.23			
		23	M	May 1999 – Jan 2001	North	0.81	+ 0.05
					South	0.74	

The difficulty of analysing the "pulses" of activity on the descending phase starts from their definitions. In the panels of Fig. 1 these "pulses" can clearly be seen, as well as the fact that they do not appear simultaneously in the two hemispheres, but they present a certain delay. We have chosen to select the pulse intervals over the entire disk and to calculate the  $Q_{x,m}$  index separately for both hemispheres, corresponding to these intervals (see Table 4).

The values obtained for the  $Q_{x,m}$  index prove an increased energy of the SXR flare activity and a degree of asymmetry differing from that of the descending phase of the cycle. Therefore, even if in SC 21 the asymmetry is larger than in the descending phase, it keeps a southern dominance, while for SC 22 two of the pulses show a northern preference, contrary to the whole cycle, which is southern dominant. This could be due to a certain influence of the new magnetic dipole appearing after the polarity reversal. The northern dominance of the solar activity (and of SXR flares, too) for SC 23 may confirm this hypothesis.

## 5. CONCLUSIONS

It is difficult to define an index that encompasses all information about the energy emitted by solar eruptive phenomena (flares, coronal mass ejections and active protuberances). The number of these phenomena reflects, unambiguously, the 11-year solar activity cycle. Attempting to evaluate, as accurately as possible, the energy emitted by such phenomena through an index is useful for understanding the dynamical evolution of the solar magnetic field and of the solar cyclic activity, in general.

Although the existence of a N-S asymmetry in solar activity is generally accepted, this phenomenon has not been fully interpreted yet. If a qualified explanation can be found, it could add precious information to the solar dynamo theory. In particular, studies on the distribution of flares seem to be very important, as active regions producing flares and active regions with low activity could originate from different levels of the convection zone (Bai, 1987; 1988). Flares may therefore originate in active regions anchored deep in the convection zone, probably at the boundary of giant convective cells (Garcia, 1990). More than 50% of flares occur in less than 4% solar area, namely in the "energetic flare zones" (as defined by Verma et al., 1987) providing large concentration for very energetic solar phenomena. Therefore, we believe that above all the other solar activity phenomena, it is worth studying the asymmetry of solar flares in as many aspects as possible.

In this context, our study leads to the following conclusions:

1. The N-S asymmetry, as computed by us, is in agreement with the results from the literature.
2. Through the degree of the N-S asymmetry for both  $N$  and  $Q_{x,m}$  indices, we found a confirmation of the antiphase SXR flare emergence for spectral classes M & X, and class C, respectively, noted by Mariş et al. (2000).
3. The asymmetry of the  $Q_{x,m}$  index is almost zero during the maximum phases of the cycles, a feature identified by many authors, for all the indices used.

4. The strange behaviour of SXR flare activity on the SC 22 descending phase could be caused by the "abnormal" appearance of SC 23, e. g., the new magnetic dipole, responsible for the SC 23 activity, begins to lose part of its energy even during the descending phase of SC 22, so that the activity of SC 23 proves to be well below predicted values.

5. Finally, we consider that the detailed study of the descending and minimum phases of the SCs, at the stage when magnetic phenomena from both the old and the new cycle interact in the solar atmosphere, would be useful for inferring information about the activity level of the next cycle.

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