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North–South Asymmetry of Solar Activity during Cycle 23

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Abstract. In this paper, we have made a statistical analysis of solar Hα flares that occurred during the period 1996 to 2005 to investigate their spatial distribution with respect to northern and southern hemispheres of the Sun. The analysis includes a total of 21608 single events. The study shows a significant N−S asymmetry which is persistent with the evolution of the solar cycle. The flare activity favors the northern hemisphere in general during the rising and maximum phase of the solar cycle (i.e., in 1997, 1999, and 2000), while the declining phase (i.e., from 2001 to 2005) shows a southern dominance. Further, the monthly N−S asymmetry index for flares, sunspot numbers and sunspot areas suggests similar variations for these phenomena with the progress of solar cycle. We also find that in terms of asymmetric behavior of solar flares, cycle 23 seems to act quite differently from cycle 22 but comparably to cycle 21.

1. Introduction

The occurrence of various features of solar activity is not symmetric considering their manifestation in the northern and southern hemispheres of the Sun. This phenomena, known as North−South (N−S) asymmetry, has been studied using several solar activity indices such as flares, sunspot numbers, sunspot areas, prominences & filaments, magnetic flux, coronal intensity, etc. by various authors (Newton & Milson 1955; Howard 1974; Roy 1977; Vizoso & Ballester 1987; Garcia 1990; Verma 1993; Ataç & Özgüç 1996; Li et al. 1998; Temmer et al. 2002; Joshi & Joshi 2004; Knaack et al. 2004; Brajša et al. 2005; Temmer et al. 2006). These studies reveal the existence of a real N−S asymmetry that has bearing with the solar dynamo mechanism (Ossendrijver 1996).

In this paper a detailed analysis of N−S asymmetry has been performed with solar Hα flares that occurred during solar cycle 23. The study covers almost full solar cycle 23 (1996−2005) and is an extension of our earlier analysis (Joshi & Pant 2005). In Section 2, the pattern of flare occurrence is studied with respect to heliographic latitudes and the significance of observed N−S asymmetry is evaluated using binomial probability distribution. The study also throw light on the evolution of flare activity with the progress of solar cycle. Further, the comparison of asymmetric behavior of flare activity is made with sunspot numbers and areas which is presented in Section 3. The results of the study are discussed in the final section.

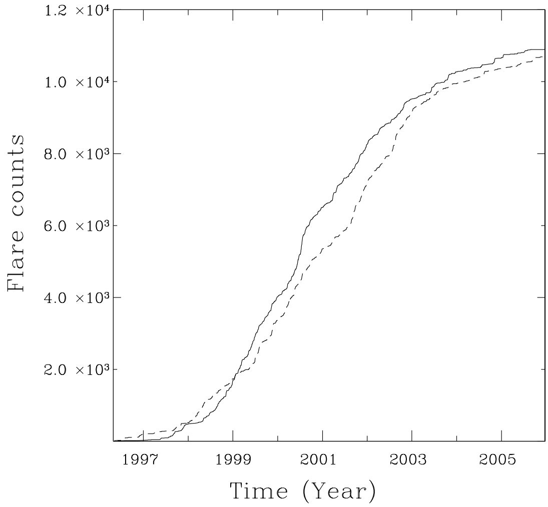

Figure 1. Cumulative counts of flares occurring in the northern (solid line) and southern hemispheres (dashed line).

2. N−S Distribution and Asymmetry of Solar Flares

The data used in the present study have been collected from Hα flare lists published in the SGD (Solar Geophysical Data) from 01 May 1996 to 31 December 2005, covering 10 years of solar cycle 23. Out of 21620 flares, 21608 events are selected for the study for which complete information about the heliographic location (latitude and longitude) was available. To study the latitudinal distribution of flares with solar cycle evolution, we compute the yearly flare counts in 10° latitudinal bands (within ±50° latitudes, flares above 40° latitudes being very small) in the northern and southern hemispheres from 1996 to 2005 (Table 1). We find that the yearly flare counts in the northern and southern hemispheres show an asymmetry (column 8 of Table 1). To evaluate the statistical significance of observed asymmetry we have used binomial probability distribution (see Joshi & Pant 2005 and references therein). The cumulative binomial probability of getting more flares in one of the hemispheres and consequently the dominant hemisphere is also given in the table (see columns 9 and 10). In Fig. 1, N−S asymmetry has been presented by plotting the cumulative counts of flares in the northern (solid line) and southern (dashed line) hemispheres during cycle 23. The vertical distance between solid and dashed lines is a measure of northern/southern excess up to that time. To compare the N−S asymmetry observed in flares with sunspot areas and numbers, we plot the monthly absolute asymmetry index ($\Delta = N_{\mathrm{N}} - N_{\mathrm{S}}$; see Ballester et al. 2005) for all these phenomena in Fig. 2.

Table 1. Number of Hα flares at different latitude bands in the northern (N) and southern (S) hemispheres are tabulated for each year. The binomial probability (Prob.) and the dominant hemisphere (DH) is given for all the years as well as for all the latitudinal bands. A dash (−) specifies that the probability is not significant. Flares occurring exactly at the equator have been excluded.

Years		Number of flares							Prob.	DH
		0-10°	10-20°	20-30°	30-40°	40-50°	> 50°	Total		
1996	N	21	2	0	1	0	0	24	1.107×10^{-33}	S
	S	112	53	21	2	0	0	188		
1997	N	39	160	230	20	0	0	449	5.641×10^{-6}	N
	S	5	103	199	18	1	1	327		
1998	N	13	635	503	54	1	1	1207	0.428	–
	S	3	366	807	31	9	0	1216		
1999	N	169	1240	811	105	11	0	2336	7.017×10^{-30}	N
	S	71	874	644	38	0	0	1627		
2000	N	463	1327	633	55	1	2	2481	8.712×10^{-14}	N
	S	248	1288	373	79	1	0	1989		
2001	N	503	978	262	5	1	0	1749	0.058	S
	S	449	1062	282	42	8	0	1843		
2002	N	250	746	255	6	0	0	1257	1.329×10^{-35}	S
	S	675	1006	272	4	0	0	1957		
2003	N	407	315	14	3	0	0	739	0.069	S
	S	222	475	83	17	0	0	797		
2004	N	231	159	0	0	0	0	390	0.123	–
	S	165	254	4	0	0	0	423		
2005	N	56	176	1	0	0	1	234	9.054×10^{-6}	S
	S	219	117	0	0	0	0	336		
Total	N	2152	5738	2709	249	14	4	10866	0.134	–
	S	2169	5598	2685	231	19	1	10703		
Prob.		0.398	0.095	0.371	0.205	0.189	0.0625	0.134	–	
DH		–	N	–	–	–	–			

3. Results and Conclusions

1. We find a significant N−S asymmetry in solar flare occurrence during cycle 23 which is persistent during the course of the solar cycle. The activity dominates the northern hemisphere in general during the rising and maximum phase of the solar cycle (i.e., in 1997, 1999, and 2000), while the declining phase (i.e., from 2001 to 2005) shows southern dominance.

2. The cumulative flare counts show a southern excess in the rising phase of the cycle (1997 to 1999), while after 1999 northern excess prevails. The northern excess first increases till mid 2001 and then decreases continuously till 2003. After 2003, we find a small but constant northern excess (cf. Fig. 1). In terms of asymmetric behavior of solar flares, cycle 23 seems to act quite differently from the previous cycle (i.e. cycle 22) but is comparable to cycle 21 (see Temmer et al. 2001 for N−S flare asymmetry during cycles 21 and 22). The different behavior of odd and even numbered cycles may be interpreted as the two parts of the basic 22-year solar periodicity (Švestka, 1995).

3. We find similar variations in N−S asymmetry of solar flares, sunspot areas and sunspot numbers during solar cycle evolution (cf. Fig. 2). However, the amplitude of N−S asymmetry, determined by the absolute asymmetry index (Δ), for different months varies between various solar activity phenomena.

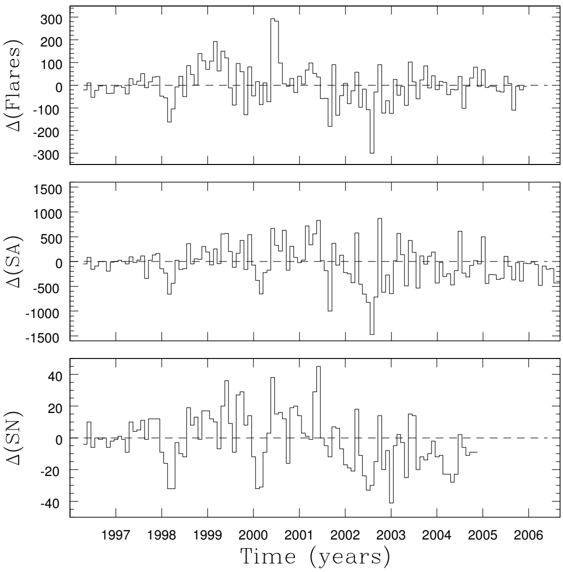

Figure 2. Monthly values of absolute asymmetry index ($\Delta = N_{\rm N} - N_{\rm S}$) during solar cycle 23. The figure shows the plots of asymmetry index for monthly flare counts, monthly mean sunspot areas (SA) and monthly mean sunspot numbers (SN) (from top to bottom panel).

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