ON THE DISTRIBUTION AND ASYMMETRY OF SOLAR ACTIVE PROMINENCES

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Abstract. The paper presents the results of a study of the distribution and asymmetry of solar active prominences (SAP) for the period 1957–1998 (solar cycles 19–23). The east-west (E-W) distribution study shows that the frequency of SAP events in the 81–90° slice (in longitude) near the east and west limbs is up to 10 times greater than in the 1–10° slice near the central meridian of the Sun. The north-south (N-S) latitudinal distribution shows that the SAP events are most prolific in the 11–20° slice in the northern and southern hemispheres. Further, the E-W asymmetry of SAP events is not significant. The N-S asymmetry of SAP events is significant and it has no relation with the solar maximum year or solar minimum year during solar cycles. Further, the present study also shows that the N-S asymmetry for cycles 19–23 follows and confirms the trend of N-S asymmetry cycles as reported by Verma (1992).

1. Introduction

The spatial locations of solar activity phenomena on the solar disc are not uniform. The north-south (N-S) and east-west (E-W) distribution, including asymmetries, of several manifestations of solar activity have been studied earlier by various authors. Several authors have studied the occurrence of solar flares as a function of distance from the central meridian (Waldmeier, 1948; Waldmeier and Bachmann, 1959). The E-W asymmetry of solar phenomena was first studied by Maunder (1907) and later on by Letfus (1960), Letfus and Růžičková-Topolová (1980) and Heras *et al.* (1990). The literature also indicates that several solar activity phenomena show some form of north-south (N-S) asymmetry (Bell and Glazer, 1959; Bell, 1962; Roy, 1977; Verma, 1987). Bell (1962) finds long-term N-S asymmetry in the sunspot area data. Roy (1977) studied the N-S distribution for flares, sunspots and white-light (WL) flares for a period of more than two solar cycles and found that the asymmetry in the northern hemisphere increases with the importance of solar events. Hansen and Hansen (1975) are of the view that the overall filament configuration and their evolution with time compactly represent the general topology of the photospheric magnetic field and its evolution during the course of solar cycles. Reid (1968) reported N-S asymmetry in the favour of the northern hemisphere for the period 1958–1965. Howard (1974) studied solar magnetic flux data from 1967 to 1973 and found that the northern hemispheric flux exceeds by 7% the southern hemispheric flux. White and Trotter (1977) investigated the asymmetry

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of sunspot area and found that on average the solar magnetic field cycle occurs uniformly in the northern and southern hemisphere. Swinson, Koyama, and Saito (1986) also examined relative sunspot numbers and sunspot areas. Their analysis shows that the N-S asymmetry of sunspot numbers favours the northern hemisphere in the period 1947–1984 (solar cycles 18–20). Verma (1987) studied six types of solar phenomena for solar cycles 19, 20, 20, and 21. These include major flares, type II radio bursts, white-light (WL) flares, solar gamma-ray (SGR) bursts, hard X-ray (HXR) bursts, and coronal mass ejection (CME) events. Verma (1987) found that the asymmetries in major flares, type II radio bursts and WL flares favour the northern hemisphere during solar cycles 19 and 20, asymmetries in type II radio bursts, WL bursts, SGR bursts, HXR bursts and CME events favour the southern hemisphere during solar cycle 21. Vizoso and Ballester (1987) studied the N-S asymmetry in sudden disappearances of solar prominences during solar cycles 18–21 and found that the asymmetry curve can be fitted by a sinusoidal function with a period of 11 years. Verma (1992, 1993) studied the N-S asymmetry of various solar activity phenomena and reported cyclic behaviour. E-W and N-S asymmetries for solar phenomena were studied together by Růžičková-Topolová (1974) and Knoška (1985). Joshi (1995) studied E-W and N-S asymmetry of solar prominences, Hα and sunspot groups and concluded that solar flares have E-W and N-S asymmetries while solar prominences have only N-S asymmetry and no E-W asymmetry during the maximum period of solar cycle 22. Recently, Ataç and Özgüç (1996) studied the N-S asymmetry in flare index and found a periodic behaviour.

The present paper investigates the E-W/N-S distribution and asymmetry of SAP events for the period 1957–1998 and will also discuss the results obtained in light of earlier works.

2. Observational Data and Analysis

The data for SAP events for the period 1957–1998 used in the present study have been downloaded from website created by National Oceanic and Atmospheric Administration, Boulder Colorado, USA. The URL address of this website is as follows: *http://ftp.ngdc.noaa.gov*/STP/SOLAR_DATA/FILAMENTS. The solar active prominence data included in the present study include limb and disc features and events. In the present study solar active prominence events include events in an active surge region, active prominences, active dark filaments, disappearing filaments, mound prominences, bright surges on limb, eruptive prominences on limb, loops, sprays, arch filament systems, dark surges on disc, bright surges on disc, solar sector boundaries, coronal rains and cap prominences. We have downloaded solar active prominence data from the above website for the period August 1957–1998 in yearwise format. From the yearly data of SAP events we have calculated E-W and N-S distributions and also studied asymmetry.

TABLE I
Yearly numbers of SAP events in the eastern hemisphere

Year	10°	20°	30°	40°	50°	60°	70°	80°	90°	Total
1957	68	93	106	71	62	40	26	18	800	1284
1958	203	219	212	205	164	111	109	81	1960	3264
1959	136	146	138	124	118	105	96	71	1510	2444
1960	107	120	148	101	102	109	55	33	1195	1970
1961	70	68	73	57	48	37	23	27	542	945
1962	57	30	51	52	42	21	24	26	418	721
1963	70	72	76	52	51	38	15	11	316	701
1964	73	68	63	49	67	20	17	6	462	825
1965	132	118	115	77	64	40	22	31	607	1206
1966	253	283	288	221	190	180	98	59	1238	2810
1967	257	237	266	271	195	133	120	82	1942	3503
1968	237	198	190	163	168	110	76	67	1900	3109
1969	84	64	49	60	56	27	19	27	458	844
1970	136	126	98	84	66	55	46	52	1239	1902
1971	174	188	175	124	81	53	42	43	1800	2680
1972	352	277	230	234	171	123	80	56	2107	3630
1973	180	176	155	152	113	84	58	68	1122	2108
1974	50	60	39	40	34	32	31	9	162	457
1975	76	60	65	64	51	36	22	12	795	1181
1976	52	55	54	39	39	44	19	13	589	904
1977	31	31	31	12	23	20	19	6	486	659
1978	30	41	44	53	30	32	13	11	887	1141
1979	52	66	46	42	38	40	23	17	697	1021
1980	82	70	52	53	30	25	14	3	844	1173
1981	59	56	43	53	32	29	18	3	664	957
1982	30	53	34	47	17	21	11	4	543	760
1983	39	35	30	30	20	11	8	3	376	552
1984	57	63	58	47	41	28	18	10	492	814
1985	54	51	56	33	33	25	21	6	580	859
1986	169	159	165	130	142	130	93	43	455	1486
1987	279	326	261	265	208	184	150	109	540	2322
1988	494	453	449	415	368	293	197	139	1220	4028
1989	451	513	490	468	409	334	260	199	2166	5290
1990	619	638	610	610	531	471	382	255	1144	5260
1991	619	582	613	573	542	523	414	251	1232	5349
1992	537	500	545	549	487	408	343	218	840	4427
1993	525	507	485	451	500	430	355	223	1057	4533
1994	384	410	366	336	323	263	199	131	404	2816
1995	322	313	249	248	240	180	132	73	411	2168
1996	172	133	140	132	94	56	48	26	178	979
1997	189	195	207	162	148	125	84	40	140	1290
1998	85	77	56	55	61	44	36	9	68	491

TABLE II

Yearly numbers of SAP events in the western hemisphere

Year	10°	20°	30°	40°	50°	60°	70°	80°	90°	Total
1957	83	79	71	62	70	63	35	23	885	1371
1958	181	147	151	172	159	127	69	52	1952	3010
1959	153	149	95	128	120	91	58	60	1402	2256
1960	116	110	105	89	110	83	69	35	1181	1898
1961	62	67	58	64	40	41	32	25	573	962
1962	54	53	55	37	42	25	16	18	416	716
1963	79	74	80	36	35	24	21	13	378	740
1964	60	62	66	77	49	45	21	14	502	896
1965	89	104	120	97	70	39	22	15	492	1048
1966	274	250	256	221	171	129	75	61	1250	2687
1967	291	213	255	221	201	140	124	148	2144	3737
1968	217	237	198	196	159	97	69	61	1998	3232
1969	60	61	44	54	55	31	17	27	471	820
1970	116	93	105	77	64	46	42	37	1312	1892
1971	162	120	155	90	72	58	30	44	1542	2273
1972	304	250	217	215	170	126	79	54	1937	3352
1973	187	176	158	125	141	80	66	36	1231	2200
1974	39	53	48	54	46	47	28	16	215	546
1975	99	99	82	102	70	63	29	19	852	1415
1976	56	38	51	49	31	26	25	3	570	849
1977	29	23	31	31	15	18	10	2	407	566
1978	35	58	55	49	34	27	15	16	813	1102
1979	45	55	40	51	51	27	23	11	595	898
1980	93	53	69	45	46	41	21	11	651	1030
1981	55	44	36	36	20	13	5	5	478	692
1982	32	24	28	24	15	13	6	6	497	645
1983	31	28	29	27	20	17	13	4	375	544
1984	58	51	61	47	29	19	15	10	475	765
1985	45	46	40	48	37	25	8	1	566	816
1986	195	188	161	145	125	114	103	64	497	1592
1987	312	285	285	198	162	178	103	82	505	2110
1988	448	485	438	401	379	316	185	161	1344	4157
1989	554	469	469	489	397	361	279	216	2244	5478
1990	795	725	724	630	566	497	360	297	1620	6214
1991	727	700	676	637	594	506	450	316	1399	6005
1992	687	690	653	600	557	568	430	269	980	5434
1993	599	608	552	555	496	442	320	217	1050	4839
1994	427	387	383	382	365	305	244	146	587	3226
1995	285	221	231	222	195	159	80	51	406	1850
1996	206	170	163	133	119	86	75	28	257	1237
1997	157	180	177	152	129	108	54	35	201	1193
1998	60	86	68	59	62	45	30	19	133	562

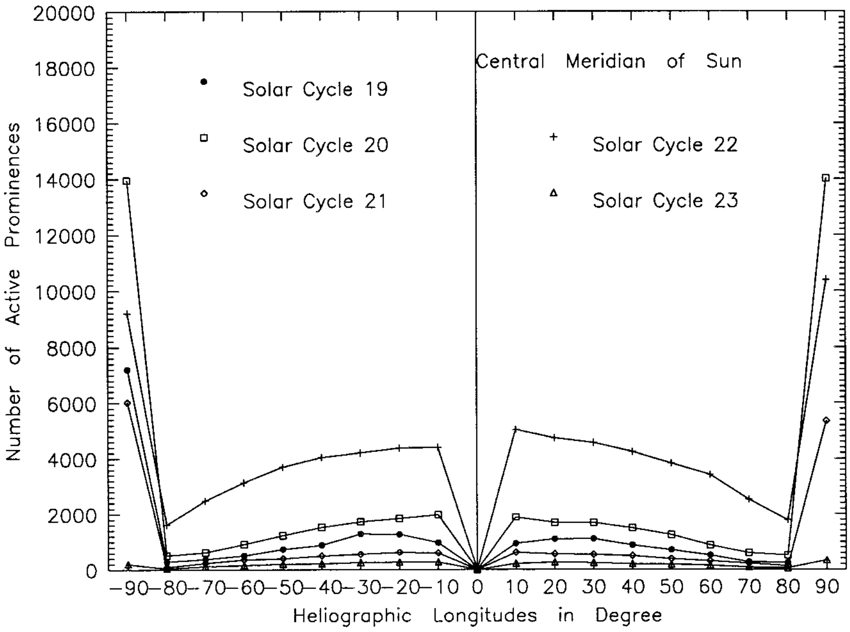

Figure 1. Plot of number of solar active prominences versus east-west heliographic longitudes in degrees.

2.1. E-W DISTRIBUTION AND ASYMMETRY OF SOLAR ACTIVE PROMINENCES

The data downloaded from NOAA, USA have been used to study the E-W distribution of solar active prominence data for the period 1957−1998. In Tables I and II we have shown the yearly distribution of SAP events at longitudinal intervals of 10° from the central meridian towards the east and west limbs, respectively, during 1957−1998.

To understand Tables I and II more clearly we have plotted the number of active prominences versus heliographic longitude in degrees (Figure 1). In Figure 1 the minus (−) sign in heliographic longitude indicates east and the plus (+) or no sign in heliographic longitude indicates west. Further, in Figure 1 the −90° represents E90 and 90° represents W90. The 0° represents the central meridian of the Sun. From Tables I–II we have calculated SAP event data for solar cycles 19 (1955–1964), 20 (1965−1976), 21 (1977−1986), 22 (1987−1996) and 23 (1997−1998) at an interval of 10°. From Figure 1 it is clear that number of SAP events decreases from central meridian towards the east or west limb of the Sun. From Tables I and II and Figure 1 it is clear that the frequency of SAP events keeps decreasing in 10° intervals from 1° up to 80°. The SAP frequency again increases between 81°−90° longitude at the east and west limbs up to 10−12 times more than in the 1°−10° slices at the central meridian of the Sun.

The E-W asymmetry indices of SAP events are calculated from the formula

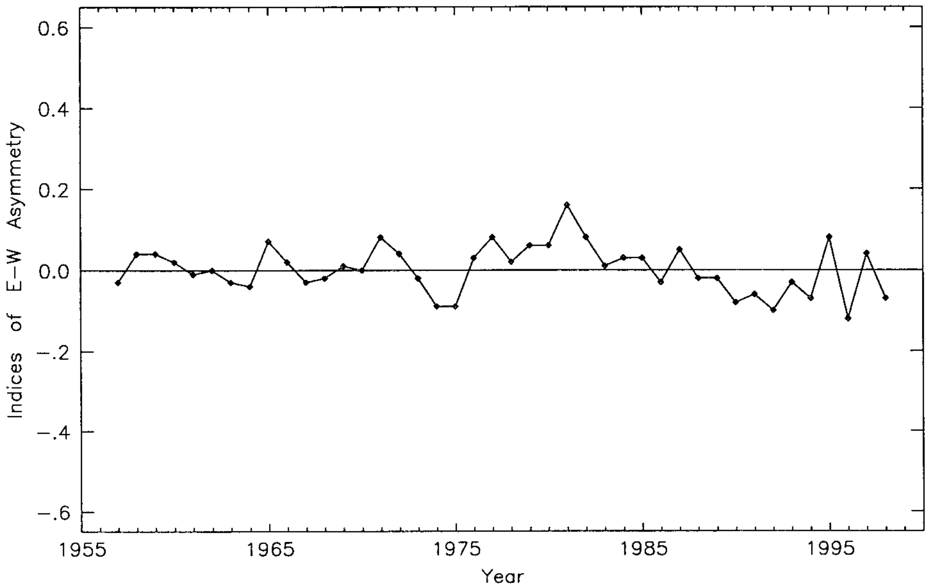

Figure 2. Plot of E−W asymmetry indices for SAP events versus year (1957−1998).

$$A_{ew} = \frac{N_e - N_w}{N_e + N_w} \, .$$

Here, A_{ew} is the E−W asymmetry, and N_e and N_w are the yearly numbers of SAP events in the eastern or western hemisphere of the Sun, respectively. Thus, if $A_{ew} > 0$, the activity in the eastern hemisphere dominates, and if $A_{ew} < 0$, the reverse is true. We have calculated the E-W asymmetries for the SAP events for the period 1957−1998. To know the statistical significance of the E-W asymmetry index we applied the χ^2 test of population variance of statistical significance. The calculated value of the Z is 0.103 at 0.01 significance level which is much less than tabulated value of Z at 0.01 significance level (2.57). Thus, we conclude that the calculated value of the E-W asymmetry of SAP data is not significant. In Figure 2 we have plotted the annual indices of E-W asymmetry versus year for SAP events.

From Figure 2 it is clear that the E-W asymmetry does not show any significant value or systematic behaviour and also that the E-W asymmetry does not show any relation with solar maximum year or minimum year during solar cycles.

2.2. N-S DISTRIBUTION AND ASYMMETRY OF SOLAR ACTIVE PROMINENCES

The solar active prominences data obtained from NOAA, USA were analysed to understand the N-S distribution and N-S asymmetry. In Tables III and IV we show the yearly number of SAP events at intervals of 10° (in latitude) in the northern and southern hemisphere for the period 1957−1998, respectively.

Using Tables III and IV we have calculated the number of SAP events in intervals of 10° (in latitude) for the northern and southern hemispheres for solar

TABLE III
Yearly numbers of SAP events in the northern hemisphere

Year	10°	20°	30°	40°	50°	60°	70°	80°	90°	Total
1957	185	450	414	176	84	36	21	17	2	1385
1958	541	886	861	479	269	137	60	56	13	3302
1959	785	1204	837	262	81	15	10	24	20	3238
1960	596	846	695	248	64	21	16	3	2	2491
1961	450	447	175	55	15	9	5	8	9	1173
1962	432	306	98	52	15	20	14	6	9	952
1963	376	507	103	54	25	6	12	7	11	1101
1964	319	195	327	179	98	51	30	33	34	1266
1965	197	284	953	222	111	35	15	16	11	1844
1966	264	1283	2255	855	140	82	31	10	5	4925
1967	346	1963	1752	431	115	46	49	5	2	4709
1968	840	1819	789	166	69	16	14	7	5	3725
1969	212	626	292	96	17	4	0	0	1	1248
1970	508	1160	464	87	24	11	9	3	1	2267
1971	893	966	262	70	37	15	9	7	4	2263
1972	1315	1179	191	75	36	31	30	22	10	2889
1973	769	940	145	50	41	28	21	35	29	2058
1974	201	149	4	3	1	0	0	0	0	358
1975	652	225	110	106	66	39	65	77	72	1412
1976	242	117	103	72	61	42	62	69	96	864
1977	79	175	185	115	43	20	35	32	38	722
1978	74	569	336	157	73	42	35	36	29	1351
1979	212	377	266	104	39	14	9	16	9	1046
1980	207	481	254	80	22	17	8	12	11	1092
1981	292	386	100	30	10	5	1	2	4	830
1982	258	315	110	32	14	9	10	8	17	773
1983	129	131	36	14	10	12	10	14	13	369
1984	207	216	81	46	11	10	12	15	8	606
1985	329	102	48	38	36	37	52	52	54	748
1986	836	208	357	141	78	21	26	33	43	1743
1987	216	339	605	329	113	43	11	14	26	1696
1988	77	1604	1751	493	126	63	35	37	47	4233
1989	397	1908	1648	649	149	106	100	69	82	5523
1990	875	2063	1065	482	102	30	20	5	5	5453
1991	1225	1402	787	328	53	10	2	1	1	4212
1992	1437	1749	435	80	32	7	0	1	5	3746
1993	2310	1787	224	43	28	29	33	53	35	4542
1994	1558	912	95	32	14	5	16	7	11	2650
1995	1140	431	49	31	29	19	38	39	64	1840
1996	611	194	91	41	31	15	11	8	12	1014
1997	194	398	657	173	27	6	2	0	4	1461
1998	8	105	173	33	8	0	0	0	1	328

TABLE IV
Yearly numbers of SAP events in the southern hemisphere

Year	10°	20°	30°	40°	50°	60°	70°	80°	90°	Total
1957	156	357	432	220	91	24	17	7	3	1307
1958	670	1181	673	240	140	56	7	16	15	2998
1959	441	516	263	114	84	16	13	0	0	1447
1960	472	550	229	48	26	22	10	3	1	1361
1961	331	218	90	26	10	14	6	3	5	703
1962	187	184	53	23	7	8	5	5	1	473
1963	125	158	20	13	11	4	1	2	0	334
1964	235	64	43	27	29	17	6	8	16	445
1965	114	79	91	60	20	19	12	14	6	415
1966	25	171	298	51	21	9	10	7	5	597
1967	130	872	1113	240	100	75	10	6	4	2550
1968	381	1177	713	217	67	44	10	2	4	2615
1969	86	196	82	44	12	1	0	0	0	421
1970	636	656	178	39	10	5	1	0	2	1527
1971	1214	1124	231	53	33	15	7	3	10	2690
1972	1819	1695	379	92	40	33	18	8	7	4091
1973	856	983	207	50	40	29	23	19	14	2221
1974	150	410	60	14	6	0	0	0	0	640
1975	437	299	72	78	67	69	54	60	48	1184
1976	260	149	136	57	59	40	50	70	65	886
1977	35	79	188	50	45	27	23	29	29	505
1978	44	223	312	149	44	30	31	31	33	897
1979	90	354	260	87	28	13	17	12	15	876
1980	212	412	334	86	37	5	3	10	17	1116
1981	268	361	137	21	16	3	5	0	0	813
1982	225	253	72	37	12	8	5	3	12	627
1983	267	270	103	37	12	12	4	11	13	729
1984	355	383	83	32	25	21	22	33	22	976
1985	243	252	109	54	51	41	53	62	60	925
1986	578	226	156	127	79	24	20	24	35	1269
1987	133	307	1432	711	116	37	4	9	11	2760
1988	99	1369	1535	625	158	81	40	25	29	3961
1989	355	2114	1389	384	125	66	38	31	40	4896
1990	1002	2142	995	407	111	29	14	1	4	5362
1991	1359	2411	1382	243	43	10	1	2	1	6432
1992	1796	2490	884	181	35	3	1	1	2	5393
1993	1670	1993	461	66	37	32	44	37	55	4395
1994	1288	1617	91	35	13	7	9	12	9	3081
1995	723	1113	121	42	30	17	16	33	23	2118
1996	653	323	110	40	25	11	9	16	12	1199
1997	92	178	581	151	32	3	0	3	1	1041
1998	6	184	379	96	43	15	0	2	1	726

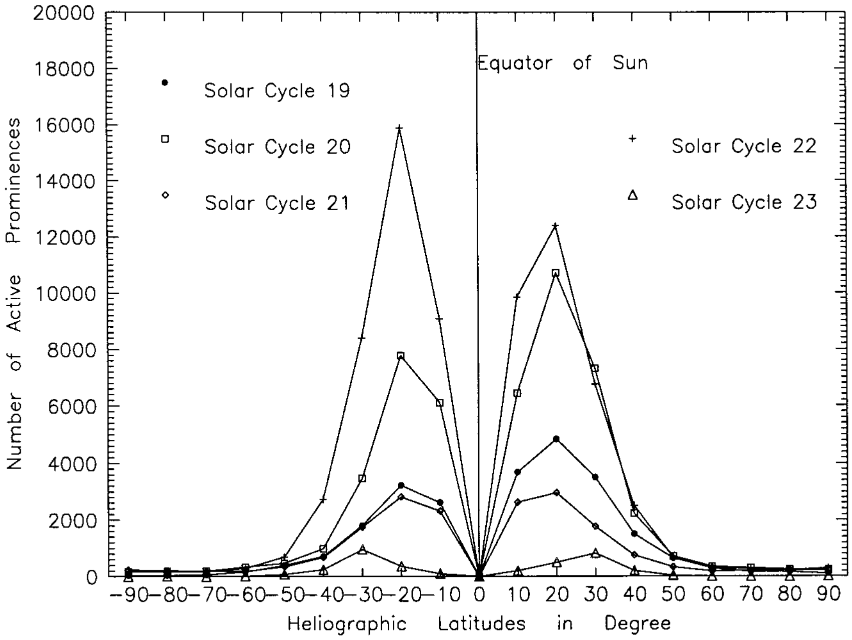

Figure 3. Plot of the number of solar active prominences versus heliographic latitude in degrees.

cycles 19, 20, 21, 22, and 23. In Figure 3 we have plotted the number of active prominences versus heliographic latitude in degrees for solar cycles 19, 20, 21, 22, and 23.

In Figure 3, the 0° latitude represents the equator of the Sun. From Figure 3 it is clear that prominence activity is maximum between 11−20° latitude in each hemisphere. The number of SAP events in the northern and southern hemispheres for the years 1957−1998 are shown in Tables III−IV. We have calculated N-S asymmetry by using the formula

$$A_{ns} = \frac{N_n - N_s}{N_n + N_s} \ .$$

Here, A_{ns} is a N-S asymmetry, N_n is the yearly number of SAP events in the northern hemisphere and N_s is the yearly number of SAP events in the southern hemisphere. Thus, if $A_{ns} > 0$, the activity in the northern hemisphere dominates, and if $A_{ns} < 0$, the reverse is true. We have calculated the N-S asymmetries with the above formula for the period 1957−1998 and plotted the indices of the N-S asymmetry versus year in Figure 4. To know the statistical significance of N-S asymmetry index we applied the Chi-Square test of population variance of statistical significance. The calculated value of the Z is 19.81 at 0.01 significance level which is much higher than the tabulated value of Z at 0.01 significance level (2.57). Thus, we conclude that the calculated value of the N-S asymmetry of SAP data is highly significant.

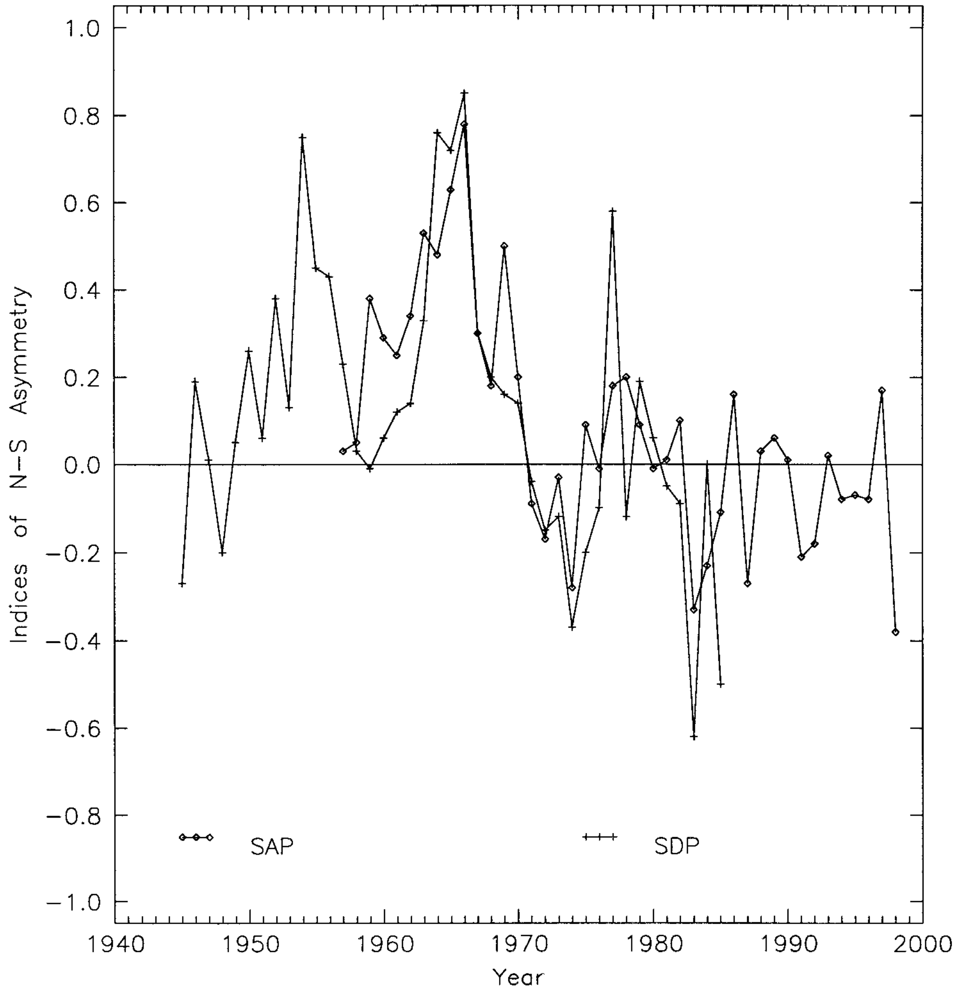

Figure 4. Plot of N-S asymmetry of SAP events versus year (1957−1998).

The N-S asymmetry of SAP events is shown by the diamond symbol in Figure 4. In Figure 4 we have also plotted the N-S asymmetry in the sudden disappearance of solar prominences (SDP) for the period 1945−1985 (Vizoso and Ballester, 1987) by the plus symbol. Figure 4 shows that there is a significant of variation N-S asymmetry indices from northern hemisphere to southern hemisphere. To know whether N-S asymmetry indices have some cyclic behaviour with solar cycles of the Sun or not we have calculated the N-S asymmetry for solar cycles number 18 −23 for SAP events and SDP events for the period including solar cycles number 18−21. In Figure 5 we have plotted indices of N-S asymmetry versus solar cycle number for the period covering solar cycles 18 to 23.

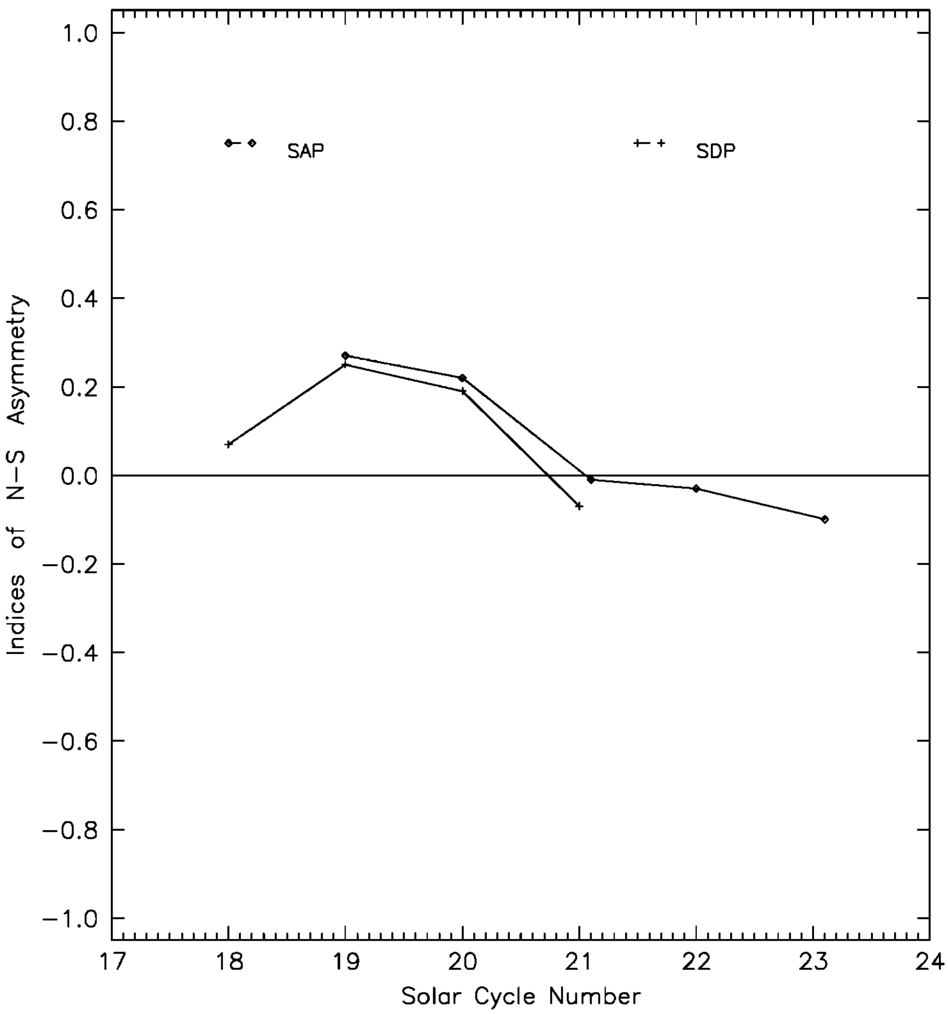

Figure 5. Plot of N-S asymmetry of SAP events versus solar cycle number.

3. Results and Discussions

The SAP events data for the period 1957–1998 are analysed and the results obtained are as follows:

(1) From the central meridian of the Sun, the frequency of SAP events decreases in 10° intervals from 01° up to 80°. The SAP frequency again increases between 81°–90° longitude near the east and west limbs by up to 10–12 times more than in the 01°–10° slice near the central meridian of the Sun.

(2) The E-W asymmetry is not significant for the period 1957–1998.

(3) The SAP events are most numerous between latitudes 11°–20° and are mostly observed within ±30° latitudes for solar cycles 19–23.

(4) The N-S asymmetry exists for SAP events during 1957–1998 and follows the trends of N-S asymmetry in sudden disappearing of prominences (Vizoso and Ballester,1987).

(5) The N-S asymmetry for SAP events also shows a cyclic variation with solar cycles.

From Tables I–II and Figure 1, it is clear that the frequency of a SAP events shows decreasing tendency from central meridian towards 80° near both limbs (east/west). It is also found that the yearly frequency of SAP events between 81 –90° is almost 70% of the total SAP events occurring in the eastern or western hemisphere. The reason for this type of distribution is not clear, but may be due to the following:

(1) Up to 50% of SAP events observed between 81°–90° may have been occurring behind the east and west limbs in the slice between 81°–90° which were observed through a coronagraph or prominence monitor leading to an increase in the yearly number of SAP events. Further, the large number of SAP events above the limb can originate from places located far from the near limb slices (81°–90° and 91°–100°). These SAP significantly increase the number of SAP attributed to the slice 81°–90°.

(2) The number of SAP events which originate on the visible part of the disk in the slices located rather close to the limb, e.g., in slices 61°–70° or 71°–80°, cannot be recorded with the Hα filters of a fixed 0.5 Å bandpass usually used for the patrol observations. Further, these SAPs, which erupt along a direction inclined towards the limb from the local vertical line, can be observed in emission above the limb, and if reported will increase the population of the slice 81°–90°.

(3) The number of SAPs observed in the central part of the disc, originating in the slices 01°–10° – up to 41°–50° or so and subsequently reported may be underestimated. This will be true for a large number of SAPs which propagate upwards with large velocity from places of origin in more or less a vertical direction and are observed mainly through Hα filters with a fixed 0.5 Å bandpass, resulting in large line-of-sight velocity components usually displayed by fast erupting prominence which makes their observation impossible.

Thus, in the light of above results the longitudinal distribution of SAP events may be treated as tentative and further investigations related to the longitudinal distribution of SAP events should be carried out with data obtained through an instruments based on tunable Hα filters. As shown in Figure 2 we have also studied the E-W asymmetry of SAP events for the period 1957–1998. The maximum E-W asymmetry index for this period was $+0.12$ and the minimum E-W asymmetry index was -0.12 and mean E-W asymmetry index was 0.04 which is not a significant value. We can also see from Figure 2 that E-W asymmetry is not following the solar cycle period of 11 years. Earlier Knoška (1985) studied the E-W asymmetry of the solar flare index for the period 1937–1976 and found that E-W asymmetry of flare activity was very small and oscillates about zero with positive number. Knoška

(1985) also compared the time variation of E-W asymmetry of flare activity with the phase of the 11 year cycle and did not find any relationship.

From Tables III–IV and Figure 3 it is clear that 11–20° latitudes in the northern and southern hemispheres are most prolific for SAP activity for the period of solar cycles 19–22 while solar cycle 23 (1997–1998) shows that the 21–30° latitude is most prolific for SAP activity. From Table II we have also calculated N-S asymmetry for the 1957–1998 and plotted it by a diamond symbol in Figure 4 along with SDP with a plus symbol. To understand indices of N-S asymmetry in a better way we have calculated the mean value of N-S asymmetry for the solar cycle. In Figure 5 we have plotted the index of N-S asymmetry versus solar cycle number for 18–23. From Figure 5 it is clear that indices of N-S asymmetry of SDP events favour the northern hemisphere for solar cycles 18, 19, and 20 and shift to southern hemisphere during solar cycle 21. Figure 5 also shows that SAP events favour northern hemisphere during cycles 19 and 20 and favouring southern hemisphere during cycles 21, 22, and 23. Further, there is a controversy about the N-S asymmetry of solar cycle 21. According to Verma (1987) and Dinulescu and Dinulescu (1990) the N-S asymmetry favour southern hemisphere during solar cycle 21 while according to Bai (1990) the N-S asymmetry is zero. The N-S asymmetry of solar cycle 21 is an important parameter because according to Verma (1992, 1993) the N-S asymmetry was favouring the northern hemisphere till solar cycle 20 and shifted to southern hemisphere during cycle 21. We conclude from Verma (1992) and also from this analysis that the N-S asymmetry will favour the southern hemisphere from solar cycles 21–24 and shift to the northern hemisphere from solar cycle 25. The present study based on SAP and SDP data show that during solar cycle 21, N-S asymmetry of SAP data is $A_{ns} = -0.01$ and N-S asymmetry of SDP data is $A_{ns} = -0.07$. Recently Ataç and Özgüç (1996) studied the N-S asymmetry in solar flare index and found that the dominance of flare activity in the southern hemisphere will continue during solar cycle 22 and also, dominance will gradually increase during solar cycle 23. The present study and the study of Ataç and Özgüç (1996), confirm the predictions of Verma (1992). According to Verma (1992), the N-S asymmetry of solar active phenomena may be southern dominated during solar cycles 22, 23, and 24, and will shift to the northern hemisphere during solar cycle 25. Further, the explanation of the N-S asymmetry period is not available in the literature and may be due to asymmetric internal structure of the Sun.

4. Conclusions

In the above sections we have carried out a detailed study about the distribution and asymmetry of SAP events for the period 1957–1998 (solar cycles 19–23). From the present study we draw the following conclusions:

(1) The east-west (E-W) distribution study shows that the frequency of SAP events in the 81–90° slice (in longitude) near the east and west limbs is up to 10 times greater than in the 01°–10° slice near the central meridian of the Sun.

(2) The latitudinal distribution study shows that SAP events are most numerous at latitudes 11–20° in the northern and southern hemispheres and SAP activities are mostly limited to ±30° in latitude.

(3) The E-W asymmetry is not of significant value and it oscillates about zero with mean value 0.04.

(4) The N-S asymmetry of SAP events has a significant value. The maximum value of A_{ns} in northern hemisphere is 0.78 and the maximum value of A_{ns} favouring the southern hemisphere is −0.38. Further, the N-S asymmetry for SAP events has no relation with a solar maximum year or solar minimum year during solar cycles.

(5) The N-S asymmetry for solar cycles 19–23 follows and confirms the trends reported by Verma (1992).

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