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North–south asymmetry of different solar activity features during solar cycle 23

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ABSTRACT

A study on north–south (N–S) asymmetry of different solar activity features (DSAF) such as solar proton events, solar active prominences [total, low (⩽40°) and high (⩾50°) latitudes], Hα flare indices, soft X-ray flares, monthly mean sunspot areas and monthly mean sunspot numbers carried out from May 1996 to October 2008. Study shows a southern dominance of DSAF during this period. During the rising phase of the cycle 23 the number of DSAF approximately equals on both, the northern and the southern hemispheres. But these activities tend to shift from northern to southern hemisphere during the period 1998–1999. The statistical significance of the asymmetry time series using a χ^2-test of goodness of fit indicates that in most of the cases the asymmetry is highly significant, meaning thereby that the asymmetry is a real feature in the N–S distribution of DSAF.

1. Introduction

The occurrence of various solar activity features show non-uniformity over the solar disk. It has also been noticed that more activity features occur in one part of the solar hemisphere than the other at any time. When these features are examined with respect to equator of the Sun, they are referred to as the north-south (N–S) asymmetry. The N–S asymmetry of several solar activity features viz. relative sunspot numbers (SN), sunspot groups, sunspot areas (SA), solar flares, Hα flare indices (Q), soft X-ray flares (SXR), solar active prominences (SAP), coronal mass ejections, radio bursts, solar gamma ray bursts, coronal holes, faculae, green corona, corona's ionization temperatures and magnetic fluxes have been investigated by various authors (Maunder, 1904; Howard, 1974; Roy, 1977; Vizoso and Ballester, 1987; Bai, 1990; Oliver and Ballester, 1994; Joshi, 1995; Ataç and Özgüç, 1996, 2006; Verma, 2000; Temmer et al., 2001, 2002; Joshi and Joshi, 2004; Joshi and Pant, 2005; Gao et al., 2007; Chang, 2008; Li et al., 2003; Li et al., 2009; Joshi et al., 2009; Joshi et al., in press).

Bell (1962) has found long term N–S asymmetry in the SA data for solar cycles 8–18. As N–S asymmetry of daily SA is a good indicator of magnetic activity, Carbonell et al. (1993) using χ^2-test of goodness of fit presented a thorough study of N–S asymmetry and established its high significance. A detailed study has been carried out by Verma (2000) to decipher N–S asymmetry of SAP during 1957–1998. Li et al. (2003) studied the asymmetry of the SAP at low (⩽40°) [SAP(L)] and high (⩾50°) [SAP(H)] latitudes, from 1957 to 1998 (solar cycles 19–22). SXR flare indices are strengthened during minima. The existence of N–S asymmetry for these during solar cycles 21, 22, 23, has been analyzed and reported by Joshi and Joshi (2004). Joshi and Pant (2005) investigated the N–S asymmetry of Hα flare events also during solar cycle 23. Zaatri et al. (2006) studied the N–S asymmetry of meridional and zonal components of horizontal solar subsurface flows during the declining phase of solar cycle 23 (2001–2004). More recently, asymmetry of solar activity in cycle 23 has been studied by Li et al. (2009) using sunspot groups and SA from May 1996 to February 2007. They have found solar activity dominance in the southern hemisphere for cycle 23. Joshi et al. (2009) studied the asymmetry of SAP and groups of different limb and disk features of SAP for solar cycle 23 and presented a comparison of these features during cycles 20, 21, 22 and 23.

In the past, the N–S asymmetries of several solar activity features on the entire solar disk and atmosphere have been studied by various researchers (e.g. Waldmeier, 1971; Verma, 1987, 1992, 1993; Ballester et al., 2005). Waldmeier (1971) studied asymmetry of most of the striking features of solar activity in the decade 1959–1969 on the two hemispheres and found that on the northern hemisphere spots, faculae and prominences were numerous and the white light corona was brighter than on the southern hemisphere. He also found that the green coronal line

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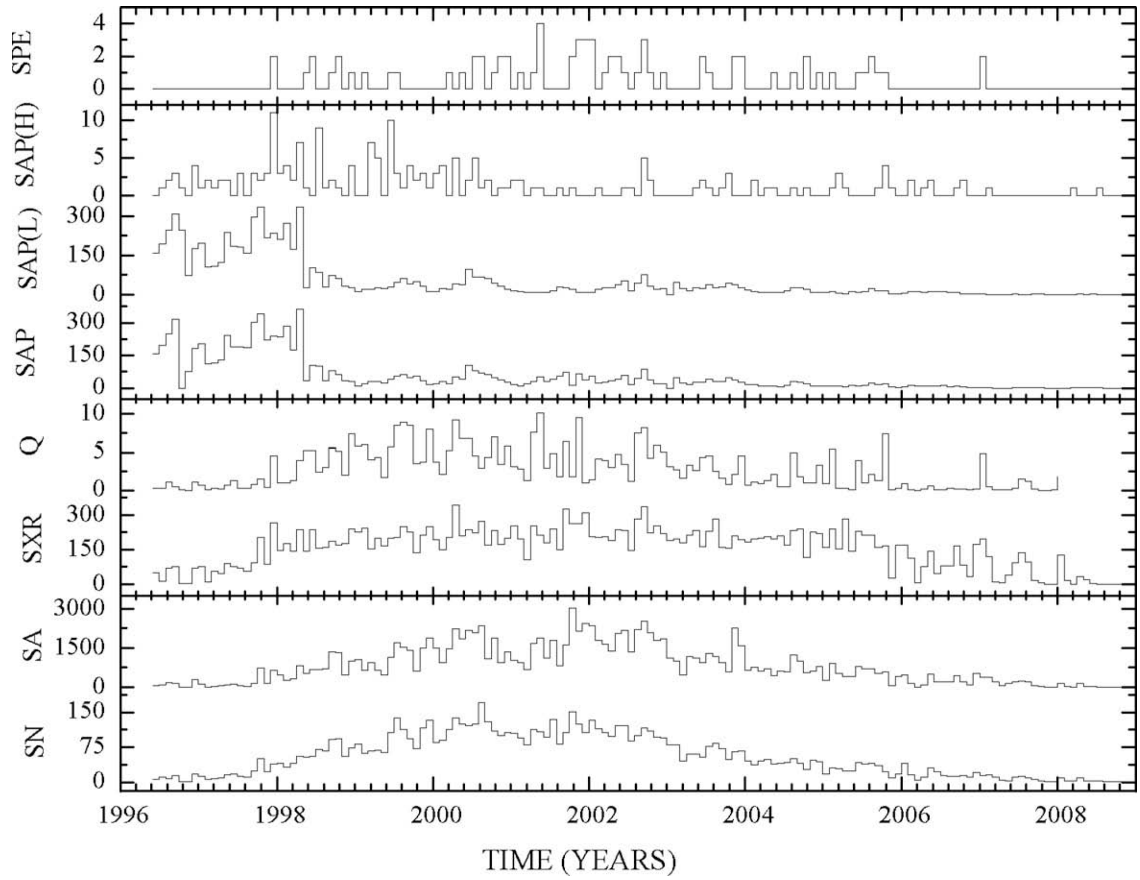

Fig. 1. Monthly plot of different solar activity features; solar proton events (SPE), SAP at high latitudes (SAP(H)), SAP at low latitudes (SAP(L)), total solar active prominences (SAP), Hα solar flare indices (Q), soft X-ray flares (SXR), sunspot areas (SA) and sunspot numbers (SN) from May 1996 to October 2008 (from top to bottom panel).

Table 1
Total number of DSAF in northern and southern hemisphere during solar cycle 23.

Solar active feature	Total number	Total number (N+S)	Total north number (%)	Total south number (%)	Dominant hemisphere
SAP	7913	7830	3623 (46.27%)	4207 (53.73%)	S
SAP(L)	–	7394	3473 (46.97%)	3921 (53.03%)	S
SAP(H)	–	189	77 (40.74%)	112 (59.26%)	S
SXR	23,301	12,097	5114 (42.29%)	6979 (57.71%)	S
SPE	72	71	36 (50.7%)	35 (49.3%)	–
SN (monthly mean)	–	682.53	321.33 (47.08%)	361.2 (52.92%)	S
SA (monthly mean)	–	10091.16	4676.98 (46.43%)	5397.66 (53.57%)	S
Q (yearly)	–	443.53	232.59 (50.31%)	229.75 (49.57%)	–

was brighter on the northern hemisphere, and the intensity of the red line was more in the southern hemisphere. Further, a comprehensive study was carried out by Verma (1987) on N–S asymmetry for major flares (solar cycles 19 and 20), type II radio bursts (solar cycles 19, 20 and 21), white light flares (solar cycles 19, 20 and 21), gamma ray bursts, hard X-ray bursts and CMEs (solar cycle 21). He reported that the asymmetry is in favor of the northern hemisphere during solar cycle 19 and 20 but favors the southern hemisphere during solar cycle 21. Verma (1992) also predicted that the N–S asymmetry in solar cycles 22, 23 and 24 may be southern dominated and would shift to northern hemisphere during solar cycle 25. Verma (1993) studied various solar phenomena occurring in both northern and southern hemispheres of the Sun for solar cycles 8-22, calculated the N–S asymmetry indices for these solar phenomena and plotted them against the number of solar cycles. Similarly, Ballester et al. (2005) have studied N–S asymmetry using different phenomena of solar activity. Summaries of the studies of hemispherical asymmetries of solar activity have been included in the works of Vizoso and Ballester, 1990, Li et al., 1998 and Li et al., 2002. Statistical analyses show that the N–S asymmetry is