On Long-Term Period of North-South Asymmetry of Solar Phenomena

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Abstract. The long-term behavior of North-South (N-S) asymmetry related to solar activity phenomena are investigated. In the investigation we have used sunspots area data (1821-2013), flare index data (1936-2013) and solar active prominences (1957-2011) data for various solar cycles. The statistical technique was used check the validity of asymmetry. Earlier Verma (1992, 1993, and 2009) reported long-term cyclic period 11 solar cycles in N-S asymmetry and also predicted that the N-S asymmetry of solar activity phenomena during solar cycles 21, 22, 23 and 24 will be south dominated and the N-S asymmetry will shift to north hemisphere in solar cycle 25. The present study shows that the N-S asymmetry during solar cycles 22 and 23 were southern dominated as predicted by Verma (1992). The initial years (2008-2013) of solar cycle 24th are showing northern domination but we must wait for another 5-6

years to confirm the result of Verma (1992). The 11 solar cycle's periodic behavior of the Sun may be related to internal structure of the Sun. The result of this study may be helpful to understand long-term helioseismic phenomena and dynamo models of the Sun which are based on the magnetic fields related to solar active regions.

1. Introduction

The various solar activity parameters in the northern and southern hemispheres cannot be considered as symmetric, as studied first by Newton and Milson (1955). In fact, there is evidence in the literature that several solar phenomena exhibit some form of north-south (N-S) asymmetry (Bell & Glazer 1959, Bell 1961, Bell 1962, Roy 1977, Verma 1987, Verma 1993, Verma 2000). Bell (1961) presented evidence of a striking N-S asymmetry in the number of major flares. During the years 1937 through 1959, about 62% of the 580 observed major flares occurred in the northern solar hemisphere. Bell (1962) finds long term N-S symmetry in the sunspot area data for solar cycles 8-18. 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 & Hansen (1975) studied the positions of filaments from 1964 to 1974. In the first half of 1964, the filament activity occurred pre-dominantly north of the solar equator. Gradually, filaments formed in the southern hemisphere so that, by mid cycle in 1969-1970, the distribution was about equal in both hemispheres. In 1974, filament activity became slightly higher in the southern hemisphere. Reid (1968) reported N-S asymmetry in favor of the northern hemisphere for the period 1958-1965. Howard (1974) studied solar magnetic flux data for 1967 to 1973 and found that the northern hemisphere flux exceeds by 7% over the southern hemisphere flux. White & Trotter (1977) investigated the possibility that sunspot areas could be asymmetrically distributed. They find that on an average the solar magnetic cycle occurs in the northern and southern hemisphere. Swinson, Koyama, & Saito (1986) also examined relative sunspot numbers as well as sunspot area. Their analysis shows that the N-S asymmetry of sunspot numbers favors northern hemisphere in the period 1947-1984 (solar cycles 18-20). Verma (1987) studied six types of solar phenomena for solar cycles 19, 20 and 21. These include major flares, type II radio bursts, 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 favor the northern hemisphere during solar cycles 19 and 20 and asymmetries in type II radio bursts, WL bursts, SGR bursts, HXR bursts and CME events favor the southern hemisphere during solar cycle 21. Vizoso and Ballester (1987) have studied the sudden disappearance (SD) of solar prominences during cycles 18 – 21 and found that the N–S asymmetry curve is not in phase with the solar cycle and peaks at or around the solar minimum and that the asymmetry changes its sign during the maximum, at the time of reversal of the Sun's general magnetic field. Verma (1992) reported long-term cyclic period 12 solar cycles or about 110 yrs in N-S asymmetry of solar active phenomena and also predicted that the N-S asymmetry of solar activity phenomena during solar cycles 21, 22, 23 and 24 will be southern dominated and the N-S asymmetry will shift to northern hemisphere in solar cycle 25. Verma (1993) further reported that N-S asymmetry shows a trend of long-term characteristic time scale of about 110 years after a study of various solar phenomena occurring in both northern and southern hemispheres for solar cycles 8-22. Atac and Ozguc (1998) studied the N–S asymmetry during solar cycle 22 with different manifestations of solar activity and confirm the prediction of Verma(1992). Verma (2000) estimated N-S asymmetry index for solar active prominence for period 1957-1998. Joshi and Joshi(2004) calculated N-S asymmetry of soft X-ray flare index for solar cycles 21, 22 and 23 and reported that during solar cycles 21, 22 and 23 solar X-ray flares index show dominance in southern hemisphere.

The above works of many investigations show mixed results. The present paper investigates the N-S asymmetry of sunspot area for solar cycles 6 to 24 (1821-2013), N-S asymmetry for solar flares data for solar cycles 17 -24 (1936-2013) and N-S asymmetry for solar active prominences (SAP) for period solar cycles 19-24 (1957-2011). Combining all types of solar phenomena for solar cycles 6-24 (1821-2010), we have investigated the possible period of N-S asymmetry of the solar activity cycles.

2. Observational Data, Analysis and Results

The data for the various solar activity phenomena used in the present study are downloaded from website created by National Oceanic and Atmospheric Administration, Boulder Colorado, USA. The URL address of this website is as follows:

ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/

The N-S asymmetry index for sunspot area, flares in and SAP events is calculated from the formulae given below:

$$A = [N - S] / [N + S] \qquad (1)$$

Here, *A* is the N-S asymmetry, and *N* and *S* are the yearly numbers of sunspot area, flares in and SAP events in the northern and southern hemisphere of the Sun, respectively. Thus, if $A > 0$, the sunspot area, flares in and SAP events activity dominates in the northern hemisphere, and if $A < 0$, the sunspot area, flares in and SAP events activity dominates in the southern hemispheres. In Figure 1 we have shown plot of year versus N-S asymmetry index of sunspot area for period 1821-2013, solar flares data for period 1936-2013 and solar active prominences (SAP) for period 1957-2011.

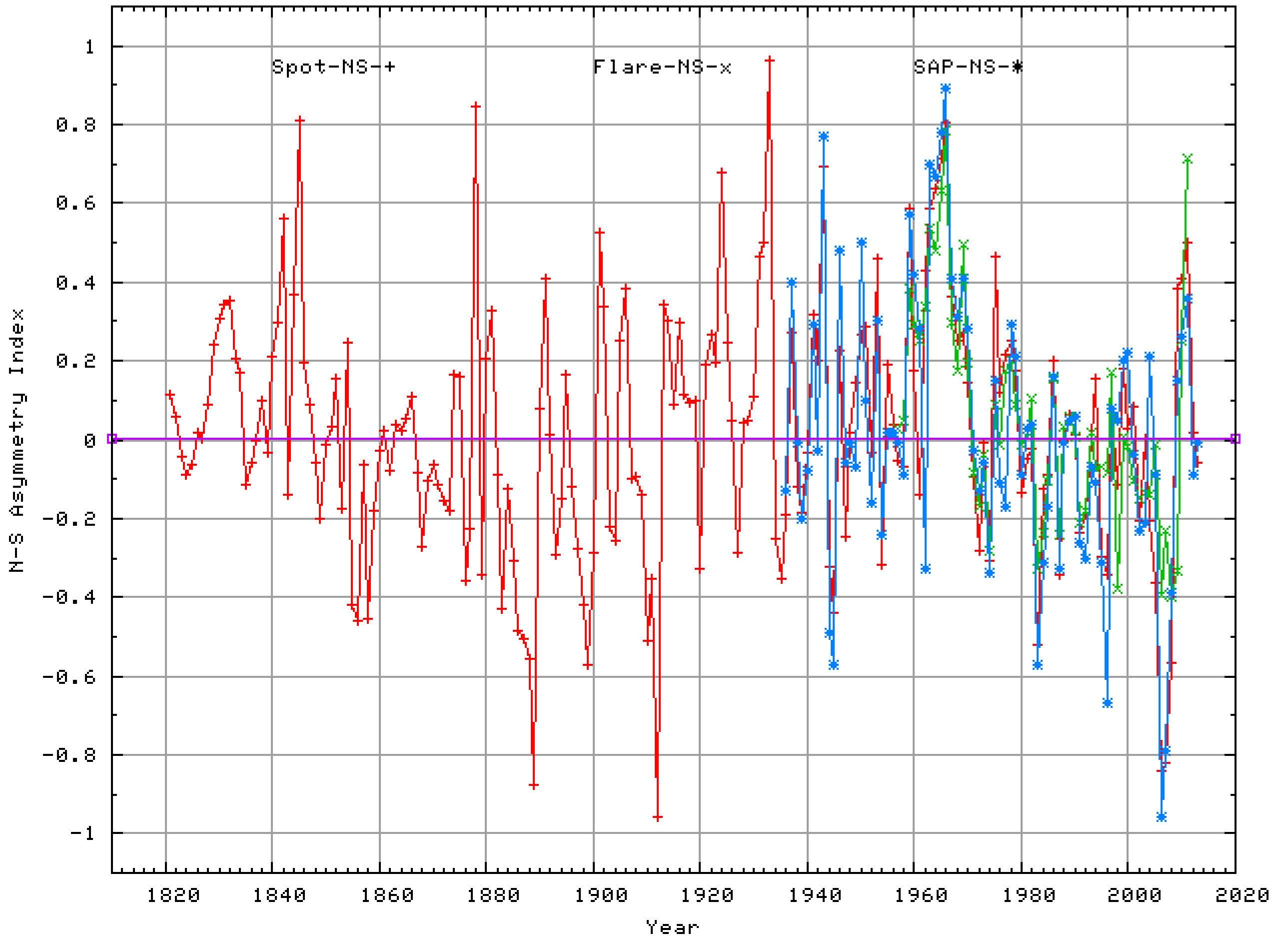

Figure 1 shows plot of Year versus N-S Asymmetry Index.

The mean value of N-S asymmetry of sunspot area, solar flares and SAP data for solar cycles 6 to 24 are plotted in Figure 2.

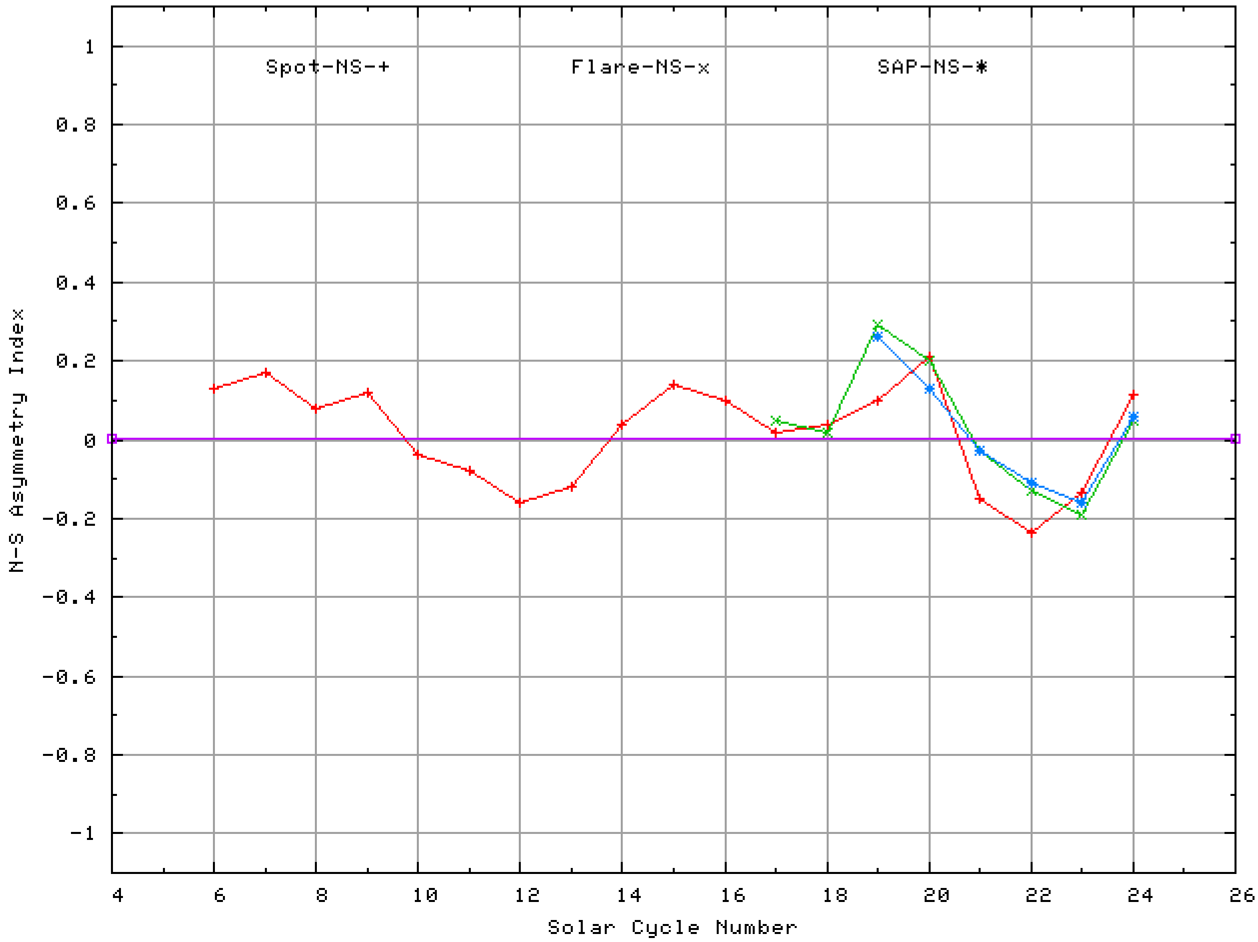

Figure 2 shows plot of Solar Cycle Number versus N-S asymmetry of sunspot area, solar flares and SAP data for various cycles.

To investigate to what extent the asymmetry is real we have followed the method of Letfus (1960) in which we can define the asymmetry of random distribution on the solar disk as:

$$\Delta Ans = \pm 1 \,/\, \sqrt{2}\,(N + S) \qquad (2)$$

Which depends upon the values of yearly number of sunspot area, flares in and SAP events in the northern and southern hemisphere respectively. To verify the reliability of calculated asymmetry values, χ 2 tests is applied with

$$\chi 2 = 2(N-S)/\sqrt{2}(N+S) = \sqrt{2}\, Ans \,/\, \Delta\, An \quad (3)$$

Thus for Ans < ΔAns, **ΔAns ≤** Ans < 2ΔAns and Ans ≥ ΔAns, the probability that N-S asymmetry exceeds the dispersion value is p < 84 %, 84 % ≤ p < 99.5 % and p ≥ 99.5 % respectively. Here the first, second and third limits imply for the statistically insignificant, significant and highly significant values respectively. Using above methodology we find that the calculated value of the N-S asymmetry of sunspot area, flares in and SAP events is statically significant.

3. Summary and Conclusions

Briefly, in the present investigation we have studied the N-S asymmetry for the period embracing solar cycles 6-24. We have calculated the N-S asymmetry indices for three solar phenomena. The study indicates that N-S asymmetry may have a long-term characteristic time scale of about 11 solar cycles. The present study shows that during solar cycles 21, 22 23 and initial years of cycles 24 the N-S asymmetry favors southern hemisphere which confirm the earlier result Verma (1992). In the present investigation the initial years (2008-2013) of solar cycle 24th are showing northern domination and this is against the Verma (1992) results for solar cycle 24. The final value of N-S asymmetry for solar cycle 24 of spot area, solar flares and SAP data will be decided after 5-6 years at end of cycle 24. Verma (1992) predicted that solar cycles 24 will be southern dominated and solar cycle 25 will be northern dominated. The 11 solar cycle's periodic behavior of the Sun may be related to internal structure of the Sun. The result of this study may be helpful to understand long-term helioseismic phenomena and dynamo models of the Sun which are based on the magnetic fields related to solar active regions. The cause of this long-term periodic behavior is not known but may be due asymmetric internal structure of the Sun.

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