THE NORTH-SOUTH ASYMMETRY OF SOLAR ACTIVITY

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ABSTRACT

In the present paper the North-South (N-S) asymmetry of four solar activity indices is estimated and discussed. The coronal green line intensity measurements, the Wolf numbers and the sunspot area data - all of them were subjected to analysis over the 1943-1999 period, together with the NSO/KP data on the total magnetic field flux measured from 1975. The pair comparisons of these four indices within different zones of solar latitude allowed to reveal a number of features in their mutual correlativness. As the coronal green line intensity as the sunspot area display a long-termed wave in their N-S asymmetry - about 40 years in duration. While during the first half of the interval studied the N-hemisphere dominates (with a clear maximum around 1964-66) then during the second half of the interval the activity measured over the S-hemisphere prevails. Quasi-biennial variations were identified both in the N-S asymmetry of the coronal green line brightness and that of the total magnetic flux. The performed study indicates a close relation between the global and local manifestations of solar activity which are governed by the magnetic fields of different scales.

Keywords: coronal green line brightness, magnetic fields, total magnetic flux, asymmetry of solar activity

1. INTRODUCTION

A cyclic character of solar activity is already well studied in detail. Practically synchronous cyclic variations of different indices characterizing the active phenomena observed at all levels of the solar atmosphere (from the photosphere up to the corona) were revealed. One of the most interesting properties of solar activity is its N-S asymmetry, i.e., the observed "asynchronous work" of the northern and southern solar hemispheres. The N-S difference (difference index) in any index of solar activity should be considered a second order effect in comparison with the index alone. Numerous studies were devoted to the N-S asymmetry of solar activity in the past. Of the recent investigations those by Nagovitsyn (1998) and Duchlev (2001) may be mentioned. In the first paper the asymmetry was studied as an unlinear process by applying the wavelet analysis to three different indices. About 45-year period in the N-S asymmetry was found in this work. In the second paper the N-S asymmetry of the long-lived filaments was estimated. As for the N-S asymmetry in the coronal green line brightness, it was treated to be determine in the papers by Sykora and Badalyan (1999) and Sykora et al. (2001).

The present paper deals with the cyclic variations in the N-S asymmetry of the following solar activity indices:

- Intensity of the coronal green emission line Fe XIV 530.3 nm. This data is based on the patrol observations of a small worldwide network of high-altitude coronagraphs and covers the 1943-1999 period. All measurements of different observatories were transformed to the former photometric scale of the Pic-du-Midi Observatory (Sykora, 1971; Sykora, 1992). A more detailed description of this database is also given in Badalyan et al. (2001). The database gives the coronal green line intensities with a step of ~13° of solar longitude (one day) and 5° of solar latitude.
- Area of the sunspot groups. This data of the Greenwich Observatory (accessible till 1997) was obtained through Internet.
- Total magnetic field flux. The data regularly observed at Kitt Peak Observatory was also taken from Internet.
- The Figure of the SIDC Brussels illustrated the N-S asymmetry of the smoothed sunspot numbers from 1955 till 2001 is from Internet, as well.

The N-S asymmetry index was calculated by the standard way as (N-S/N+S), where N and S denote the val-

ues of the corresponding parameter for the northern and southern hemispheres, respectively.

2. BASIC RESULTS

Intensity of the coronal green line represents a very appropriate index allowing the solar activity being studied over the whole range of solar latitudes simultaneously. Sykora and Badalyan (1999) and Sykora et al. (2001) showed that, the coronal green brightness does not change simultaneously at N and S solar hemispheres. At the same time, the changes in the N-S asymmetry are practically synchronous for all latitudinal zones of the Sun. A consideration of N-S asymmetry within the zones 10° in width revealed that within these relatively narrow zones the sudden changes of the sign of asymmetry are sometimes observed. The characteristic sharp turns in the curves of asymmetry are related to these asynchronous fast increases or decreases of the coronal green line brightness at corresponding latitudes in the north and south solar hemispheres (Figure 1, the upper panel).

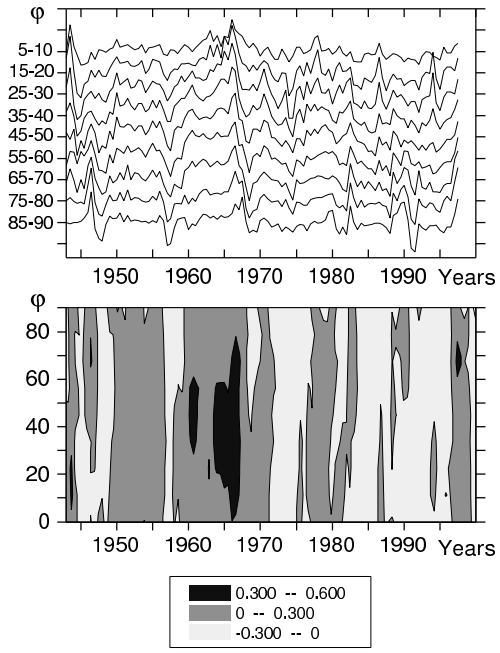

Figure 1. The evolution of the N-S asymmetry of the coronal green line intensity. The upper panel shows the N-S asymmetry within the zones 10? in width. The characteristic sharp turns in the curves of asymmetry are related to asynchronous fast increases or decreases of the coronal green line brightness at corresponding latitudes in the north and south solar hemispheres. In the lower panel a time-latitude diagram of the above asymmetry is displayed

In the lower panel of Figure 1 a time-latitude diagram of the above asymmetry is displayed. One can deduce much brighter green-line corona over the N-hemisphere during the first half of the period studied, while the right part of this diagram indicates (on average) somewhat brighter corona over the S-hemisphere. Around the 1965-67 period a substantial increase of the asymmetry was observed over all the range of latitudes. This fact is evidently connected with the beginning of the 20th solar cycle for about 15 months earlier at the N-hemisphere in comparison with that at the S-hemisphere. Again the positive asymmetry (i.e., the N-hemisphere is brighter of the S-hemisphere) is expressed much more distinctly. All the said points out a relatively independent evolution of the solar cycle at both the solar hemispheres.

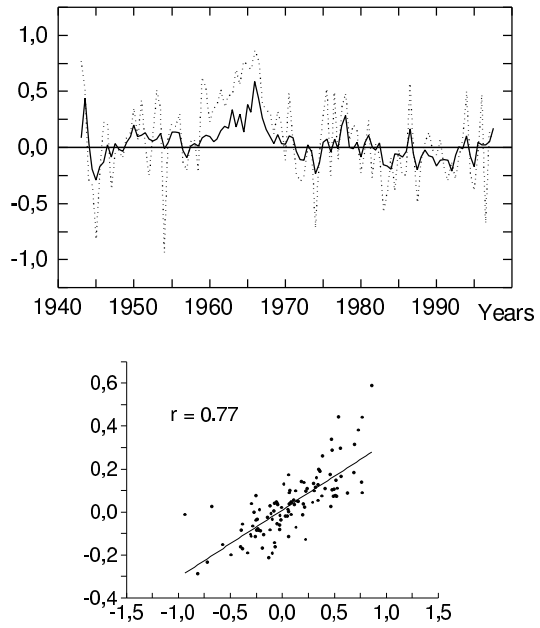

Figure 2. Indices of the N-S asymmetry as derived from the coronal green line intensity measured within the 0°-20° of solar latitude (full line) and from the sunspot area records (dotted line). In the lower panel the correlation between the above quantities is shown (the sunspot area on the abscissa and the coronal brightness on the ordinate).

In Figure 2 the index of asymmetry derived for the green-line corona 0°-20° latitudinal zone (full line) is compared with that of the sunspot area (dotted line). There is a half-year resolution in these curves. Practically synchronous course of both the curves is evident. The correlation coefficient is r = 0.77 ± 0.04 (see the lower panel of Figure 2). This, probably, reflects a close relation of the green-line brightness with a presence of the coronal active regions, most frequently appearing quite above the photospheric active regions. A considerable increase of the asymmetry indices in the middle of sixtieth may be noticed in this Figure, as well.

A not very clear fact may be pointed out. The coronal green-line asymmetry derived for the 25°-55° middle-latitude zone (where the sunspot practically absent) still well correlates with the N-S asymmetry of the sunspot areas to which, basically, the latitudes lower than 25° contribute.

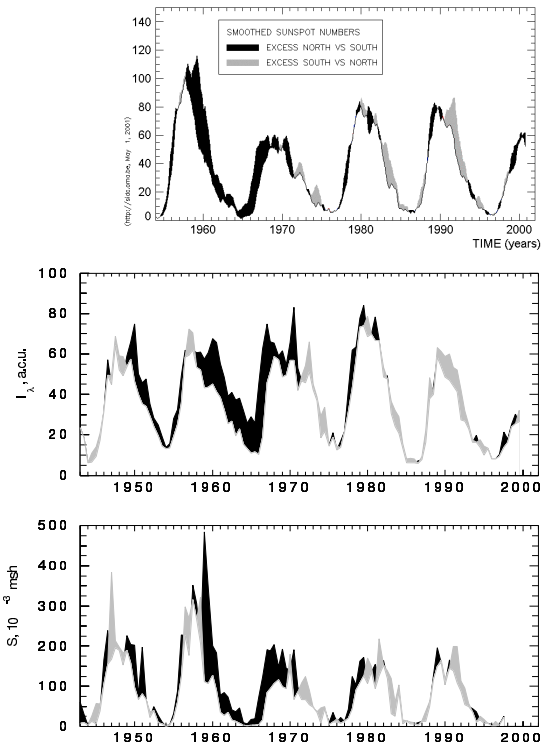

Figure 3. The cyclic variations of the sunspot numbers, the coronal green line intensity (expressed in the absolute coronal units) and the sunspot area (in the millionths of the visible solar hemisphere), all of them separately derived and drawn for the northern and southern solar hemispheres (top-down). The black areas indicate the periods when the enumerated parameters were higher at the N-hemisphere, the gray areas denote predominance of the S-hemisphere.

We have found a high correlation also between the N-S asymmetries of the coronal green line brightness and the sunspot numbers. In Figure 3 the cyclic variations of the sunspot numbers, the coronal green line intensity, and the sunspot areas, separately for the northern and southern hemispheres, are demonstrated. The regions, where these parameters are higher in the N-hemisphere in comparison with the S-hemisphere are black-drawn while the opposite ratios are shown in gray.

Evidently, the increase and decrease of the asymmetry indices are very similar in case of all the three parameters and, as for the magnitude, the variations correlate well on both the long and short time scales. Again, all three parameters exhibit a clear dominance in activity of the N-hemisphere during the first half of the interval investigated and, vice versa, the higher activity at the S-hemisphere may be noticed after about 1972. Thus, a presence of about 40-year wave in the N-S asymmetry is perceived. Nagovitsyn (1998), analyzing 175-year interval of different solar data, has obtained a 45-year N-S asymmetry wave. In addition, our Figure 3 demonstrates approximately synchronous periods of the increases (or decreases) in the N-S asymmetry in case of all the three parameters (see the broadest black and gray areas in Figure 3).

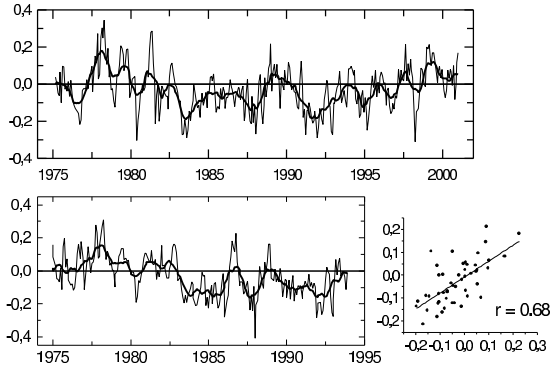

Figure 4. The N-S asymmetry derived for the total magnetic flux within the 0°-80° latitudinal zone (upper panel) and for the coronal green line intensity within the 0°-60° zone (lower panel), both given with one-month resolution. The thick lines at both panels represent the smoothed data over a 13-point window. The correlation coefficient calculated from the half-yearly averaged values of both the above N-S asymmetries is shown in the lower right-hand panel (the magnetic flux on the abscissa and the coronal brightness on the ordinate).

The comparison of the N-S asymmetry of the coronal green line brightness with that of the total solar magnetic field flux is particularly interesting. Figure 4 represent the variations of the corresponding asymmetries of the magnetic flux (upper panel) and the green-line corona (lower panel). The lower panel

We have also performed a wavelet analysis of the monthly asymmetry indices obtained for the coronal green line brightness and the total magnetic flux. The result is shown in Figure 5, the regions of lower reliability being hatched. On these diagrams a (4-6)-year period (about 1500 days) is apparent and especially well-expressed by the total magnetic flux measured close to the maximum of the solar cycle 21 (around 1990). A presence of the quasi-biennial variations is also noticeable. An attention should be focused to two regions at the upper and lower panels in the 1978-80 and 1987-89 periods. During these intervals the increase of the quasi-biennial variations in the asymmetry indices of both parameters took place, consistent not only in time but also in period.

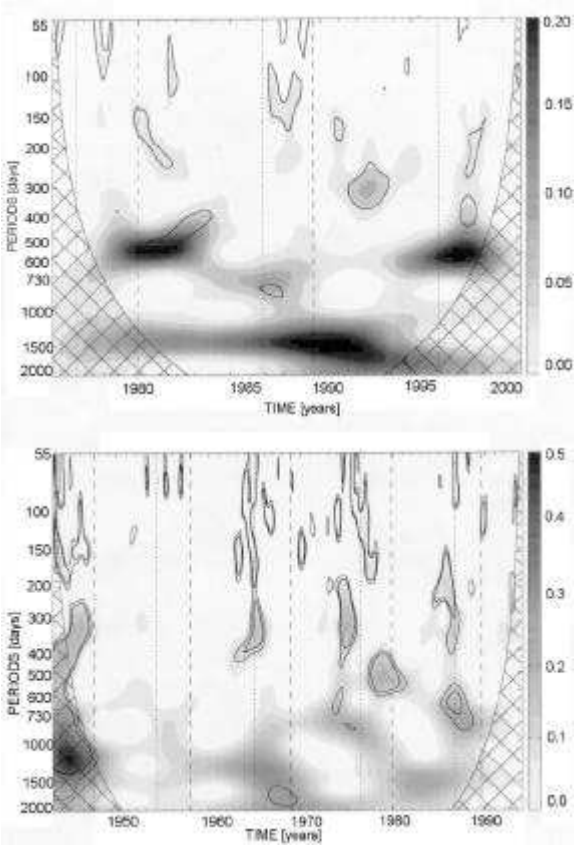

Figure 5. The wavelet diagrams as derived from indices of the N-S asymmetry of the total magnetic field flux (1975-2000, upper panel) and that of the coronal green line brightness (1943-1993, lower panel). The regions of the reduced computational reliability are hatched. The periods of oscillations in days are given on the ordinate.

3. CONCLUSIONS

Analysis of the N-S asymmetry displayed by four different parameters of solar activity gave the following results:

1. The northern and southern solar hemispheres "work" not quite synchronously. Namely, in the temporal course of the quantities investigated "a discordance" in the phase and magnitude between the hemispheres and lasting from a few months to 1.0-1.5 year is observed. This asynchronism is manifested very similarly by the different parameters of solar activity, from the photosphere up to the solar corona, as their N-S asymmetry.

2. In the temporal course of the N-S asymmetry of all the parameters analyzed the coincident variations are found both at the short and long time scales.

3. A long-wave period of about 40 years was revealed in the N-S asymmetry during 1943-2000, displaying an alternate domination of the northern and southern hemispheres in the first and the second halves of the whole interval, respectively. The highest maximum in the N-S asymmetry appeared around 1965.

4. Considerable correlation between the asymmetry indices derived for the total magnetic flux and the coronal green line brightness seems to be particularly interesting. For these two parameters the synchronous strengthenings of the quasi-biennial variations were detected being coincident temporally and also for the magnitude of period.

The nature of the N-S asymmetry of the different solar parameters is not clear until now. Any of the known solar dynamo mechanisms do not offer satisfying imagination on the asymmetrical global magnetic field structure. The N-S asymmetry of the field could be caused by a presence of the slowly varying relict field. However, there is no experimental evidence for existence of such a field and, it is questionable from the theoretical point of view, as well. Therefore, existence of the well-expressed N-S asymmetry displayed by a number of the solar activity indices represents a serious challenge for the theory of the solar magnetic dynamo.

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