N–S ASYMMETRY OF SOLAR ACTIVITY AND QUASI–BIENNIAL OSCILLATIONS

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ABSTRACT

Space-time distribution and mutual correlation of the N–S asymmetry in various indices of solar activity are considered. It is shown that changes in the N–S asymmetry variation both at short and long time scales are consonant in all activity indices under consideration. Quasi-biennial variations of the asymmetry index and their space-time distribution are revealed and examined. The conclusion can be drawn that the N-S asymmetry is a specific independent and very promising tool for analysis of the solar activity variations.

Key words: Solar activity, N-S asymmetry, quasi-biennial oscillations (QBO).

1. INTRODUCTION

At present, it is ascertained that the solar northern and southern hemispheres do not behave identically. This difference manifests itself as a north-south asymmetry. This asymmetry has been studied by many authors (e.g., see Carbonel et al., 1993, Li et al., 2002 and the references therein).

Badalyan et al. (2002) have shown that a mismatch in phase and in strength exists in the time variation of some indices in the two hemispheres, which lasts from a few months to many years. The disagreement manifests itself as the north-south asymmetry nearly in the same way in different indices from the photosphere to the corona. One can see a long-periodic (∼40 years) wave within the time interval of 1943–2000, the northern hemisphere being dominate in the first half of the interval and the southern one, in its second half.

In this work the following data have used: 1. Sunspot areas; 2. Number of sunspots. It should be emphasized that we mean the total number of sunspots rather than the traditional Wolf numbers;[1] 3. Coronal green line brightness. These data cover the interval of 1939–2001 and are based on measurements of a number of coronal observatories. All the data are reduced to a common photometric scale (Sýkora, 1971). For detailed description of the coronal database see also (Badalyan et al., 2001); 4. Total magnetic flux is recorded at the Kitt Peak Observatory from 1975 to January 2001.[2]

The asymmetry index is determined here by a standard way as $A = (N - S)/(N + S)$, where N and S are the magnitudes under consideration in the northern and southern hemispheres, respectively.

2. ASYMMETRY VARIATIONS IN DIFFERENT SOLAR ACTIVITY INDICES

Figure 1 shows the asymmetry variation of four solar activity indices within the sunspot formation zone $0° - 30°$. The original data are smoothed by the Savitzky-Golay method using the 13th-order polynomial. This method is used to suppress the noise and to keep the high-frequency components. One can see that, at short time scales, the asymmetry behaves actually in the same way in all indices under discussion.

To discriminate long-term variations the asymmetry indices were smoothed by the 49-month running mean method. Contrary to Fig.1, this method moves the high-frequency component, leaving only the slowly changing one. Figure 2 shows that, over relatively long time intervals, the asymmetry in different indices displays similar behaviour. Thus, as follows from Figs.1 and 2, the typical temporal variations of the asymmetry index are consonant in all the above-mentioned solar activity characteristics, both in short and long time scales.

The mutual correlation of the semi-annual mean asymmetry values of different solar activity indices

[1]http://science.msfc.nasa.gov/ssl/pad/solar/greenwch.htm
[2]ftp://argo.tuc.noao.edu/kpvt/synoptic/mag

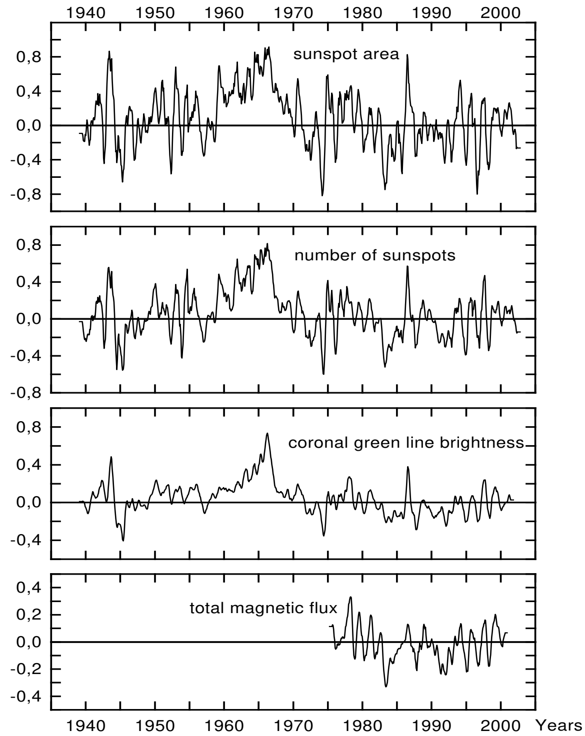

Figure 1. Asymmetry variation in four solar activity indices in the sunspot formation zone 0° - 30°.

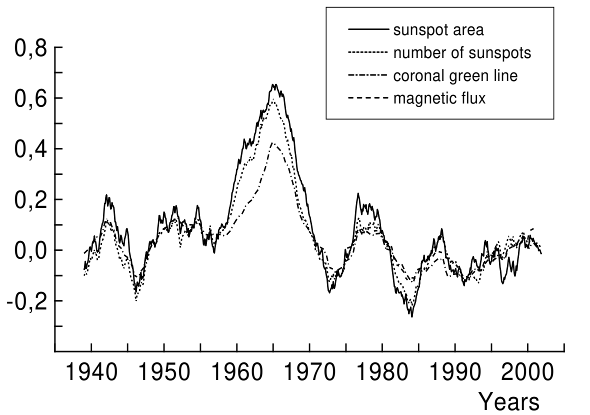

Figure 2. Long-term asymmetry variations in four activity indices in the sunspot formation zone 0° - 30°.

as a function of latitude is shown in Figure 3. The green corona brightness and magnetic flux were considered in narrow 10-degree latitudinal zones, while the sunspot areas and numbers were taken as total over the entire sunspot formation zone. The curves in Figure 3 illustrate mutual correlations in following pairs of activity indices: green line brightness (in different zones) - number of sunspots (total), 2 - green line brightness - sunspot area, 3 - green line brightness - magnetic flux (in different zones), 4 - magnetic flux - number of sunspots, 5 - magnetic flux - sunspot area.

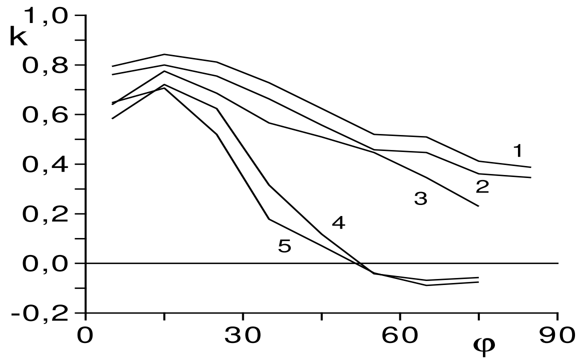

Figure 3. The mutual correlation of the semi-annual mean asymmetry values of different solar activity indices as a function of latitude.

As seen from Fig.3, the best correlation in all latitudinal zones exists between the green corona and total sunspot number. The correlation between the green-line corona brightness and sunspot area is a little bit worse. The best correlation between the asymmetry values for different activity indices is observed in the 10° - 20° latitudinal zone. In the polar zone, the correlation decreases significantly. It is interesting to note that the magnetic flux in the polar zone has a negative (though very small) correlation with the total sunspot number and area. It may suggest that in this zone, the magnetic flux is mainly determined by large-scale fields, while the green corona brightness at all latitudes depends primarily on the local field parameters.

3. QUASI–BIENNIAL OSCILLATIONS IN THE N-S ASYMMETRY

Inspection of Figure 1 suggests that the time variation of the asymmetry involves quasi-biennial oscillations (QBO). In order to study these oscillations in more detail, we have used the Spectral–Variation (SVAN) and the wavelet analyses.

SVAN is the Fourier analysis applied to successive moving intervals. The monthly mean asymmetry data have been analyzed. The moving interval was chosen to be 132 months long. Inside each interval, the data were normalized in accordance with a standard. The oscillation amplitudes were determined in the range of the periods from 6 to 44 months.

Figure 4 illustrates the SVAN diagrams for the asymmetry in the green corona brightness for narrow 10-degree latitudinal zones. The ordinate shows the period in months. The total interval of variations of the QBO amplitude is 0.26 (recall that the sum of squared amplitudes for all periods at each time point is 1.0). The total interval is divided into four grades. The darkening on each wavelet diagram corresponds to the growth of the amplitude. Figure 4 shows only the periods from 15 to 35 months (ordinate axis) corresponding to QBO. As seen from this figure, QBO

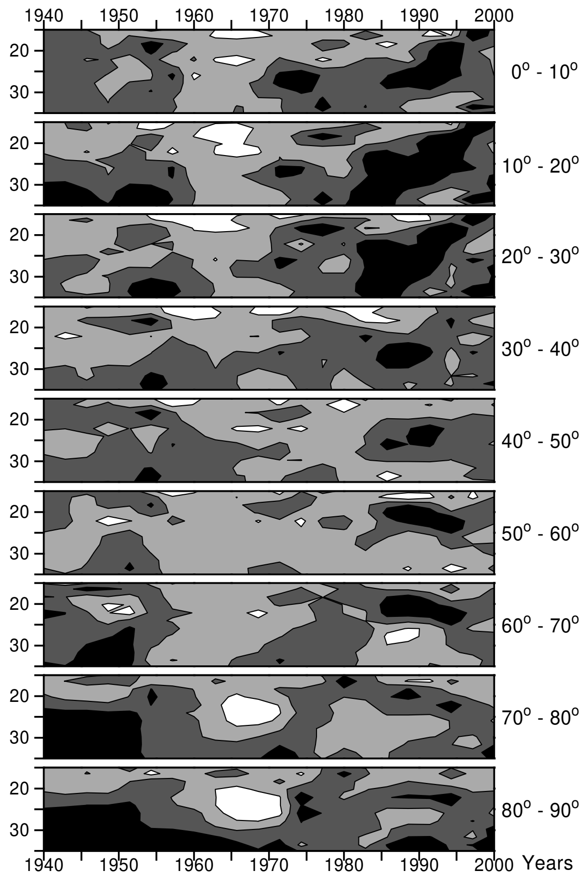

Figure 4. Spectral–Variation Analysis (SVAN) of the N–S asymmetry in the coronal green line brightness.

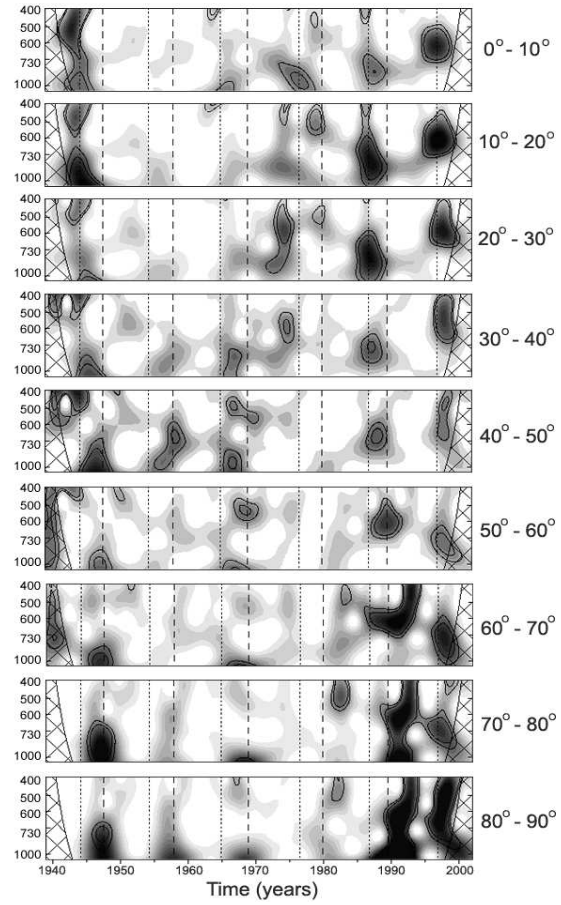

Figure 5. Wavelet analysis of the N-S asymmetry in the coronal green line brightness.

are present during most of the time interval under consideration, being particularly pronounced in the equatorial and mid-latitude zones in the 70-ies and 80-ies and in the high-latitude zone in the 40-ies. On the other hand, there is an interval (the 60-ies) when QBO are, in fact, absent at all latitudes.

The wavelet analysis was also appied on the asymmetry in the green corona brightness for individual narrow latitudinal zones (see Fig.5). As in Figure 4 dark colour corresponds to the growth of the amplitude. The ordinate shows the period in days. One can see that during 1943–1948 (ascending phase of cycle 18) and during 1984–1993 (ascending phase and maximum of cycle 22), quasi-biennial oscillations drift gradually from the equatorial zone to high latitudes. In other cycles, QBO are present for some time in a rather broad range of heliolatitudes without any noticeable drift (e.g., QBO are clearly pronounced in the latitude band of $0° - 40°$ during 1973–1974). As the SVAN diagrams, the wavelet diagrams display also a decrease of the QBO intensity in the 60-ies.

In Figure 6, SVAN diagrams for the asymmetry in the total sunspot area, total number of sunspots, and green corona brightness for the sunspot formation region of $0° - 30°$ are presented. One can see that the decrease of the QBO amplitude in the 60-ies and its significant increase in the 70-ies and later is revealed in the asymmetry of the sunspot areas and numbers. The similarity of the SVAN diagrams for the areas and numbers of sunspots can well be anticipated. However, the SVAN diagram for the green corona brightness also displays a general similarity with the former ones.

In addition to SVAN diagrams constructed for the asymmetry, SVAN diagrams for the total number and area of sunspots and the green corona brightness in the sunspot formation zone of $0° - 30°$ were also considered. Contrary to the asymmetry SVAN diagrams, the diagrams for indices themselves do not show relevant similarity. However, it is more important that no quasi-biennial oscillations are seen in the behaviour of the activity indices themselves.

4. RELATIONSHIP BETWEEN QBO POWER AND VALUES OF THE ASYMMETRY

The above-mentioned period of decreased QBO intensity in the 60-ies coincides with the increase of asymmetry in the green corona brightness and in the areas (number) of sunspots. Moreover, the inverse relationship between the QBO intensity and the asymmetry index is observed all over the time interval under investigation.

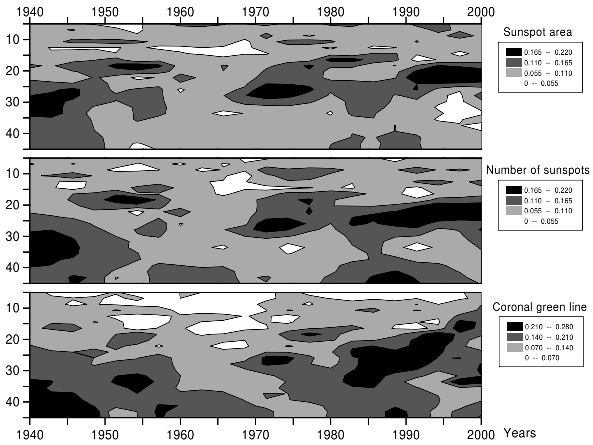

Figure 6. SVAN diagrams (from top to bottom) for the asymmetry in different activity indices for the sunspot formation zone of 0° - 30°.

The negative correlation between the QBO intensity and the asymmetry index is conserved in all latitudinal zones. The correlation coefficients depend on latitude. They reach the highest values in the latitude zones of 10° - 20° and 60° - 70°. Between the two zones, there is a narrow band of latitudes (40° - 50°), where the correlation coefficient is low. Note that it coincides with the region separating the low-latitude and polar magnetic fields.

5. CONCLUSIONS

1) We have analyzed the north–south asymmetry in 4 different indices of solar activity (coronal green line brightness, total sunspot area, total number of sunspots, and total magnetic flux). The time behaviour of the N-S asymmetry in all the indices under consideration displays similar variations at both the short and long time scales (Fig.1 and Fig.2).

2) The best correlation between the asymmetry of different activity indices is observed in the 10° - 20° latitudinal zone (Fig.3). This conclusion suggests that the green corona asymmetry is determined by a single parameter associated with the local fields. It should be emphasized that this conclusion concerns both the sunspot formation and high-latitude zones. From the indices under consideration, the sunspot areas and total number of sunspots are determined by local magnetic fields, while the magnetic flux depends on two parameters which is manifested as the sign change of curves 4 and 5 at high latitudes. These are most likely the low-latitude local fields and large-scale polar fields.

3) Quasi–biennial oscillations have been identified in the asymmetry of all activity indices under consideration and have been investigated. For this purpose, we have used an original version of the spectral-variation analysis (SVAN), which, in contrast to the other SVAN programs described in literature, includes normalization to the standard. As a result, we have found that the QBO amplitude in the asymmetry of the parameters under discussion, particularly in the green-corona brightness, varies in anti-phase with the asymmetry value itself. The correlation coefficient is $k = 0.81 \pm 0.05$ in the 10° - 20° zone.

4) The SVAN analysis shows that quasi-biennial oscillations are best pronounced in 1968–2000 in the sunspot formation zone, where they permanently exist all over the time interval under discussion, and the oscillation period is just 2 years.

5) It is shown that QBO are pronounced much better in the N–S asymmetry than in the corresponding activity indices. The QBO in the indices are poorly correlated with each other. On the contrary, the QBO spectra of different asymmetry indices are well correlated.

6) It is shown that QBO manifestations in the asymmetry of different solar activity indices and, particularly, in the coronal green line brightness are seen in anti-phase with the asymmetry magnitude itself. A remarkable decrease of the QBO amplitude has been detected in the middle of the past 60-ies. This decrease coincides with the long-lasting noticeable increase of the asymmetry indices of different solar activity parameters.

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