LONGTERM CHANGES OF SOLAR ACTIVITY ASYMMETRY

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ABSTRACT. We report results of analysis of the north-south asymmetry of solar activity, solar magnetic fields. The analysis is based on the sunspot data, 1875–2015 (http://solarscience.msfc.nasa.gov/greenwch.shtml), large-scale solar magnetic field (solar mean magnetic field, SMMF) and solar polar magnetic field time series, 1975–2015 (http://wso.stanford.edu). To study long-term changes of solar activity asymmetry we applied analysis of cumulative sum. Cumulative sum averages short-periodic changes and identifies long-term periodicity.

Minimum of cumulative sum of sunspot area mean monthly values time series occurs in ~1910, maximum – in ~1980. Perhaps this is branch growth of long-term (~140-years) cycle of solar activity asymmetry. Cumulative sums of polar magnetic field of different pole have ~22-years periodicity. Change of cumulative sum of SMMF time series has different character. But long-run trend with intervals of positive and (or) negative polarity of ~22 years is observed.

Keywords: Sun: Solar activity – Sunspots area: Solar activity – Magnetic fields: Data analysis – Methods: Cumulative sum.

1. Introduction

Solar activity (SA) is a variety of phenomena and processes associated with the formation and the decay of the magnetic field in the solar atmosphere. The most studied type of SA is variations of sunspots number. Magnetic fields on the Sun were first measured in sunspots by Hale (1908). It was established that the spots of the present cycle are opposite in polarity to those of the last cycle ("the law of polarity Hale"). It was found that the Sun's polar fields changed polarity as well. Thus, the physical cycle is 22-year cycle (Babcock, 1961).

A distinctive feature of SA is asymmetry regarding the hemispheres. It is known that the asymmetry is not random in nature, and occurs at long time intervals. To investigate the feature of SA asymmetry different methods were used : a variety of statistical tools (Carbonell et al., 1993) a wavelet analysis (Donner & Thiel, 2007), cumulative sum (Mordvinov, 2006; Leiko, 2013) et al.

The present work is continuation of investigation of long-term changes of asymmetry using different SA time series.

2. Data and Method

We applied analysis of cumulative sum (CS) of such indicators of solar activity: sunspots area data, 1875–2015

(http://solarscience.msfc.nasa.gov/greenwch.shtml), solar mean magnetic field (SMMF) and solar polar magnetic field time series, 1975–2015 (http://wso.stanford.edu).
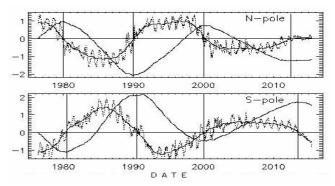

Figure 1: The solar polar field strength, in gauss (G) (line by dot, smoothed data – thin solid line) and its cumulative sums (thick solid line). Times of polar field reversals are shown by solid vertical lines.

CS adds the current value of the analyzed series with all previous, averages short-periodic changes and identifies long-term periodicity (Mordvinov, 2006; Leiko, 2013). If the CS increases, then positive values dominate, if the CS decreases, then negative values dominate. Fig. 2 presents the changes of solar polar field at N- and S-pole. Both lines of CS have wavy shape. One can see that times of reversal of magnetic field agree with extrema of CS. The distance between the two maximums or two minimums is ~22 years. So, the period of CS of polar field is solar magnetic cycle.

3. Results

The nature of the asymmetry is often characterized in different ways that can lead to different conclusions. Simply quantifying the asymmetry itself is problematic. Absolute asymmetry $NSA = A_N - A_S$ produces strong signals around the times of maxima. Relative asymmetry $NSAn = (A_N - A_S)/(A_N + A_S)$ produces strong signals in minima. And variations of these indexes are different (Leiko, 2011).

The CSs of absolute and relative asymmetry are shown on fig. 2. Both CS have wavy shape, change more or less synchronously and have one minimum and one maximum. This curve is a part of quasi-periodic process. Interval from minimum to maximum (the branch growth) is half of full period. During the interval 1875–1915 CS wanes (southern hemisphere dominates), during 1915–1980 CS increases (northern hemisphere dominates), after 1980 CS again wanes (southern hemisphere dominates). Both extremums

have two different in intensity humps, the second hump more intense in both cases. Solid thick vertical lines showing moments for these humps. The distance between first and second pairs of humps in the minimum and maximum is ~ 65–70 years. It can be assumed that the length of a full cycle should be ~130–140 years.
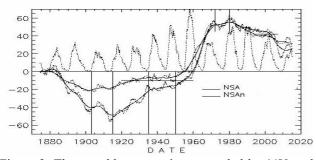

Figure 2: The monthly sunspot's area scaled by 1/50 and smoothed cumulative sums of absolute (NSA) and relative (NSAn) asymmetry.

A feature of curves CS is the availability of plateau, time intervals, when the CS almost unchanged. Plateau marked by solid thin horizontal lines, thin solid vertical lines – moments of their beginning and end. This time intervals are 1935–1950 (at branch growth) and 1995–2003 (on branch droop). In these short intervals was not dominance regarding hemispheres by index of total spots area.

Fig. 3 shows the change of SMMF values, its sector structure (upper and middle panels). On the bottom panel lines by dots are their CS, thick solid line – smoothed values of the CS of SMMF, dashed thick line – smoothed values of CS of sector structure. Oblique straight lines are their linear trends.
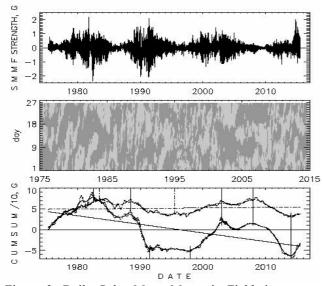

Figure 3: Daily Solar Mean Magnetic Field, its sector structure and their cumulative sums.

Although the CS curves have a different course, however, is visible in the course of synchronicity. Both curves have two maximums and two minimums, both maximum have two humps, the first minimum is the plateau, the second minimum until visible one hump. However, trends of these curves are completely different. The CS of the sector structure has almost no trend, while the cumulative sum of the SMMF has a significant trend. This means that

the sector structure having ~22 years cycle in the predominance of the square of fields of positive and negative polarities has no long cycle. A significant negative trend of CS curve of SMMF indicates that the index field value has a long cycle of changes and available monitoring interval is on decrease branch of this cycle.

We compared the curves course of the CS of daily values of SMMF and the CS of daily asymmetry of value total area of sunspots on interval 1975–2015 timeframe. Despite the different nature of these curves, their changing is synchronously to 2005.5. After this time the change occurs in antiphase. In the fig. 4 this point shows a solid vertical line across the panel. Both curves have a plateau at about the same time. One can see that the trend of these curves are almost identical. This means that the above suggestion (the asymmetry index of field value has long cycle of change and monitoring interval is on a branch of the recession this cycle) is true.
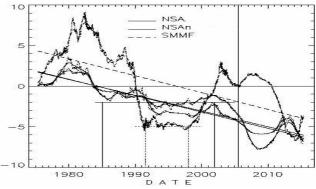

Figure 4: Cumulative sums of daily values of SMMF, sunspot's area and their trends.

Parallelism of trendlines suggests that this cycle may be the same length as the cycle asymmetry of spots area. The area of spots is proportional to the magnitude of their magnetic fields. Therefore asymmetry of magnetic fields values of both large- and small-scale have ~130-140-year cyclicity.

3. Conclusions

The long-term cycle (~ 140 years) of north-south asymmetry of solar activity was selected on the time series of the sunspot area.

Probably the photospheric large-scale magnetic fields have this long-term cycle also. But sector structure of large scale magnetic fields has not this long-term cycle.

Variations of the asymmetry of large-scale and small-scale magnetic fields (area of sunspots) are in sync until 2005.5, after this time the dynamics asymmetry passes in antiphase.

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