Astrophys Space Sci (2009) 323: 221–224
DOI 10.1007/s10509-009-0056-0

ORIGINAL ARTICLE

# Some notes concerning the prediction of the amplitude of the solar activity cycles

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Received: 13 November 2008 / Accepted: 16 June 2009 / Published online: 9 July 2009


**Abstract** The parameter $G$, which is determined from the general number of sunspots groups $N_g$ according to the daily observations $G = \sum(1/N_g)^2$, is offered. This parameter is calculated for the days when there is at least one sunspots group. It characterizes the minimum epoch solar activity. Parameter $G$ mounts to the maximum during the epoch close to the minimal activity of sunspots. According to the data of the sequence of sunspots group in Greenwich–USAF/NOAA observatory format, observation data of Kislovodsk solar station and also daily Wolf number, the changes of parameter $G$ during 100 years were reconstructed. It is demonstrated in the paper that parameter $G$'s amplitude in minimal solar activity $n$ is linked with the sunspot cycle's amplitude $W_{n+1}$ or one and half cycles. The 24th activity cycle prediction is calculated, which makes $W_{24} = 135(\pm 12)$.

**Keywords** Solar cycle · Sunspot · Activity

## 1 Introduction

The solar activity prognosis is a topical issue, relating to the applied aspects of the solar–terrestrial relationship and the fundamental nature of the solar magnetic cyclicity. Among the different methods of the amplitude of the sunspots activity cycle prognosis, the most successful are those where the solar activity precursors are used (Li et al. 2001). The results of geomagnetic activity's observation (Ohl 1970), large-scale magnetic fields (Tlatov and Makarov 2005), polar magnetic field (Svalgaard et al. 2005) and others are used as a basis for such methods.

Along with that the sunspots are the most long-term observations of the solar activity. Nowadays methods have been discovered that allow to appraise the amplitude of the sunspots activity cycle in accordance with the sunspots data. The most famous of them are the Gnevishev–Ohl' rule, the amplitude-period method, maximum–minimum method and others (Hathaway et al. 1999). As a rule, these methods allow to appraise the amplitude of the following sunspots activity cycle relying upon the characteristics of the current cycle or minimum epoch.

In this paper the method of appraising the amplitude of the sunspots activity cycle is considered, according to the number of the sunspots groups and daily Wolf number.

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## 2 The analysis of the sunspots groups' observation data

The numbers of the sunspots groups in Royal Greenwich Observatory–USAF/NOAA sunspot data were used as a basis of the analysis. These data were taken from the website http://solarscience.msfc.nasa.gov along with the data of sunspots of Kislovodsk solar station. Let us introduce parameter $G$, which is determined from the general number of sunspots groups $N_g$ according to the daily observations:

$$G = \sum(1/N_g)^2. \quad (1)$$

This parameter is calculated for the days when there is at least one group of sunspots in sight. So, for the days when the number of groups is equal to $0, 1, 2, 3, \ldots$, the parameter $G$ means amount to $0, 1, 1/4, 1/9, \ldots$ correspondingly. Figure 1 depicts the parameter $G$ behavior resulting from the monthly means smoothed with a 12-point sliding average.

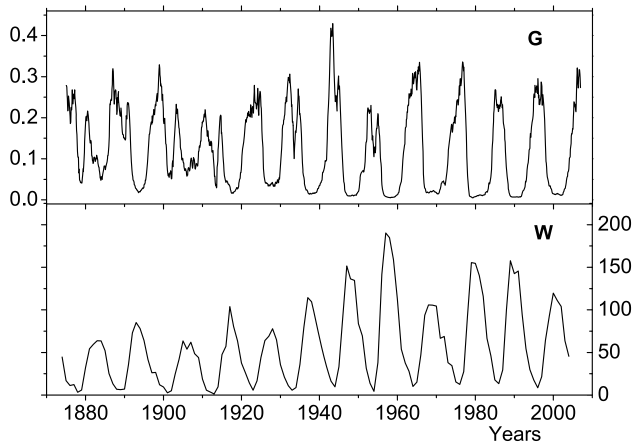


**Fig. 1** (*Top*) The parameter behavior resulting from the monthly means and smoothed by means of the sliding average method by 12 months relating to the data of Greenwich observatory format. (*Bottom*) Annual Wolf numbers

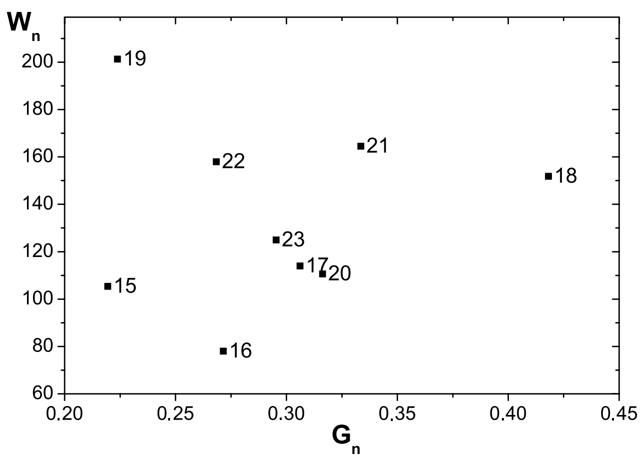


**Fig. 2** The amplitude of the sunspots activity cycles $W_n$ as a function from the $G_n$ parameter

The $G$ parameter has its maximum in the minimum activity epoch. Figures 2 and 3 show regression dependence between the amplitude of the sunspots activity in cycles $W_n$ and the amplitude of the $G_n$ and $G_{n-1}$ parameter correspondingly. The amplitude of the $G_{n-1}$ parameter precedes the amplitude of the sunspots activity cycle $n$. For cycles 16–23 this correlation may be presented as: $W_n = -30(\pm 21) + 570(\pm 71)G_{n-1}$, the standard deviation $\sigma = 12.2$ and coefficient of correlation $R = 0.956$. The 24th activity cycle prognosis according to index $G$ amounted to $W_{24} = 135(\pm 12)$.

Closely related result was received at Kislovodsk solar station. The observations of the Kislovodsk solar station have been carried on since 1954. On Fig. 4 changes of $G$ parameter throughout the period of 1954–2006 are presented. In spite of the different level of means conditioned by different systems of the sunspots groups' calculations, one observes a considerable accordance between the numbers of Kislovodsk and Greenwich observatory format data. Before

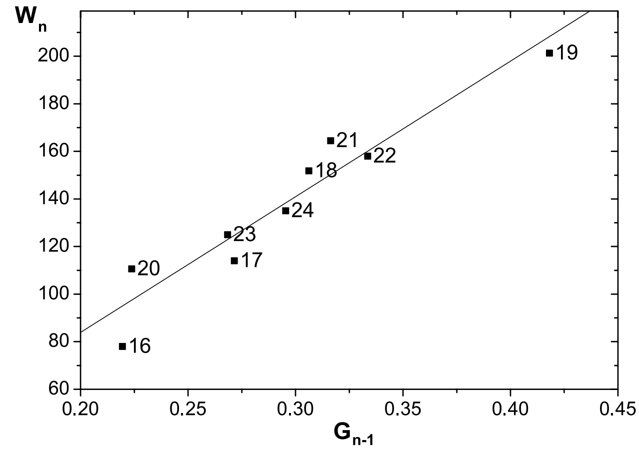


**Fig. 3** The amplitude of the sunspots activity cycles $W_n$ as a function from the $G_{n-1}$ parameter

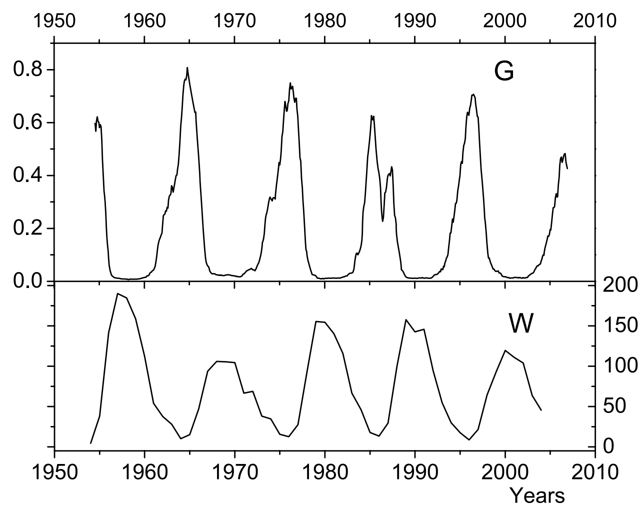


**Fig. 4** (*Top*) The variations of the parameter $G$ according to the data of the groups of sunspots of Kislovodsk solar station. (*Bottom*) Annual Wolf numbers

the 20th and 21st cycle peaks of parameter $G$ have a closer amplitude than for the amplitude of the $W$ index for activity cycles 21 and 22.

## 3 Analysis of the sunspots' data index $R_z$

In order to describe solar activity, an index of the sunspots $R_z$ is widely used. The index itself was introduced by Rudolf Wolf. The relative sunspots index is linked with the numbers of the sunspots groups $N_g$ by the correlation $R_z = k \cdot (10 \cdot N_g + n)$, where $k$ is correctional factor for an observation, $n$ is the number of the sunspots in groups. Let us consider the following procedure of getting an index analogous to $G$ with respect to daily index $R_z$. For $R_z$ means transcending 7, we will introduce a filter function equal to

$$g = 50 \cdot (1.0 - \exp(-z + 1.0 - \exp(-z))) + 7, \qquad (2)$$

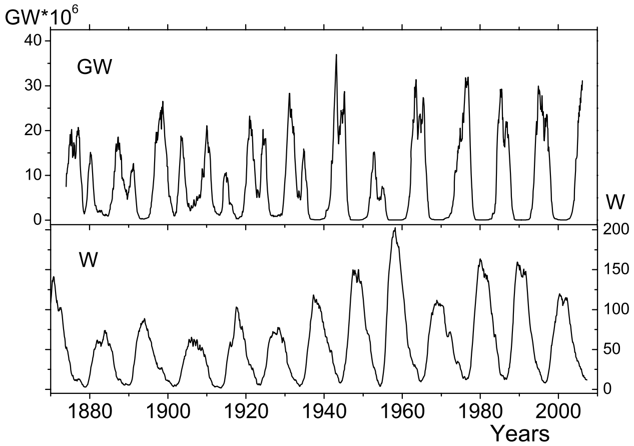


**Fig. 5** (*Upper panel*) *GW* index, received from the daily means of Wolf numbers, smoothed by 18 months. (*Lower panel*) smoothed Wolf numbers

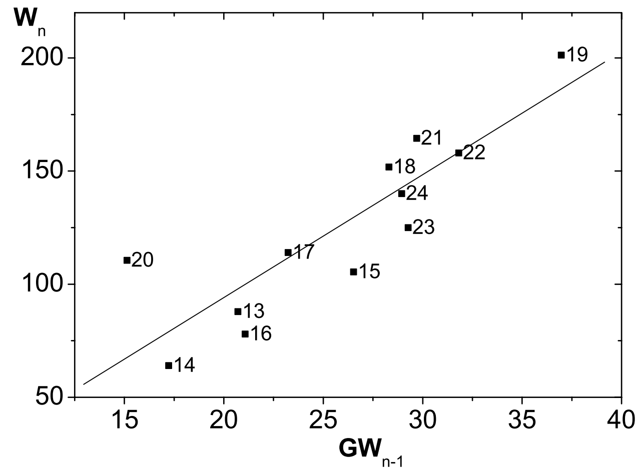


**Fig. 6** The dependence of the amplitude of activity cycles on the *GW* parameter. The 24th activity cycle prediction is calculated

where $z = (R_z - 18)/20$; and we will put $g = 50$ for $R_z < 8$. Further we will use the procedure analogous to building of the $G$ index. Thus, we will get the monthly average sums, divide them on the amount of days per month and raise to the fourth power. So, this procedure defines the *GW* 24th activity cycle prognosis parameter which results from the daily Wolf numbers. It should be noted that before the 1976 period a simpler transformation can be used. In order to do it, one should take an integer part of the $R_z/8$ meaning. Figure 5 reflects the behavior of the received *GW* parameter, smoothed by 18 months and Wolf numbers. Figure 6 shows the regression between the amplitude of the sunspots cycles and parameter *GW*. The dependence can be represented in the formula: $W_n = -14.6(\pm 27) + 5.4(\pm 1)GW_{n-1}$, the correlation level is $R = 0.865$ and a standard deviation $\sigma = 22$. The amounted to $W_{24} = 140(\pm 22)$, that is close to the index $G$ meaning.

## 4 Discussion

The method offered above allows to build solar activity indices, which reach their maximum in the minimum epoch, and the amplitude of which precedes the amplitude of the sunspots cycle. The amplitude of the new indices $G$ and $GW$ precedes the amplitude of the sunspots cycle one and a half 11-year cycles. In contrast to the indices of large-scale magnetic field and polar activities, which occur 5–6 years before the solar activity (Svalgaard et al. 2005; Svalgaard and Cliver 2007; Tlatov and Makarov 2005). Possibly, this difference is linked with the fact that indices of the large-scale field and polar activity characterize surface poloidal fields, which had already formed by the beginning of the new activity cycle, while the sunspots are connected with the poloidal field at the base of the convective zone. We can assume that the number of spots groups at the decay phase and the minimal activity characterizes residual poloidal magnetic fields for the current n cycle near the production zone. The absence of sunspots can be the result of the complete disappearance of such a field. This case corresponds to the value of the index $G = 0$. The appearance of a considerable number of sunspots groups indicates the significant transfer of the poloidal magnetic field from the production zone towards the surface, and it decreases its strength. Index is quite small. With the small quantity of registered spots $G$ index is maximal, and possibly reflects the magnitude of the residual poloidal field. If we assume, that the residual poloidal field can hold out enough time near the generation zone, it can give an additional contribution to the amplitude $n + 2$, when the direction of the poloidal field again corresponds to the direction of the field in cycle $n$. In fact, nowadays the transport dynamo models are offered, in which one uses the theory of the residual magnetic poloidal fields' existence, modulating the solar activity (Tlatov 1996; Dikpati et al. 2006). At present this theory is used for the solar activity prognosis (Dikpati et al. 2006). Perhaps, the usage of the $G$ parameter will be useful for calibration of the magnitude of the residual magnetic poloidal fields in the transport dynamo models, and that can increase the effectiveness of the solar cyclicity prognosis.

**Acknowledgements** This paper was supported by the Russian Fund of Basic Researches and to programs of the Russian Academy of Science.

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