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A method to evaluate the level of solar activity at the remainder of a progressing solar cycle

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Abstract

A modified method is developed to evaluate the level of solar activity at the remainder of a progressing solar cycle based on a method previously proposed by [Li, K.J., Zhan, L.S., Wang, J.X., et al., 2002a. A&A 392, 301]. The behavior of sunspot numbers at the remainder of cycle 23 is studied. A comparison of different methods that predict sunspot numbers of a whole cycle is also given in this paper.

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1. Introduction

Increasing attention is being paid to the long-term prediction of solar activity because of its great significance in applications (Wang et al., 2002a; Zhao et al., 2003). Sunspot numbers are usually used as an index to describe the level of solar activity of a cycle, and predictions of sunspot numbers, including the maximum sunspot number of a cycle and its timing, are very important. Predictions of the amplitude of recent cycles were summarized by Li et al. (2001).

Analysis of historical data on sunspots and related solar activities has revealed a lot of information about the sunspot cycle. Physical or statistical links and relations between sunspots and the known solar cycles obtained from these studies possibly provide some ways by which we are able to predict some parameters of the future cycle using parameters of the preceding cycles (Hong,

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1990). For example, a wide variety of geophysical precursors' methods and statistical methods has been proposed to predict the level of solar activity (e.g., see Li et al., 2001; Kane, 2001; Sello, 2001; Hathaway, 1999).

Prediction of the long-term behavior of solar activity is one of the most important tasks of solar activity predictions. Hathaway et al. (1994) studied the shape of sunspot cycles and found that the temporal behavior of a sunspot cycle can be represented by a simple function with only two parameters. With this approach, it is possible to make an estimate of the amplitude with an accuracy of within about 30% right at the start of the cycle. As the cycle progresses, the amplitude can be better determined to within 20% accuracy at 30 months and to within 10% accuracy at 42 months into the cycle, thereby providing a good prediction both for the timing and size of sunspot maximum and for the activity level of the remaining 7–12 years of the sunspot cycle. Calvo et al. (1995) used the neural network technique to analyze the time series of solar activity and to predict the long-term variation of solar activity. Tsirulnik et al. (1997) utilized a new method of nonlinear spectral analysis called the method of global minimum to predict the possible future level of the 11-year solar cycle. Li and Gu (1999) used a function similar to the Planck function to reproduce the presently known Moscow Neutron Monitor Pressure-Corrected Values (MNMPCVs) and offered predictions of future neutron count values. Then relying on the statistical correlation between MNMPCVs and sunspot numbers, they could predict the long-term variation of solar activity in the future. Wang and Han (1997, 2000) proposed a so-called "similar cycle" method to make predictions of not only the maximum amplitude of a cycle but also the variation over the whole sunspot cycle, and the verification of the predictions given by the method for the ascending and maximum phase of solar cycle 23 shows that it is a reasonable method for predicting the future level of long-term solar activity (Wang et al., 2002b). Li et al. (2002a) investigated the prospect of using signatures of previous sunspot cycles to determine future active level in an ongoing cycle, with a specific application to cycle 23 – the current sunspot cycle. A nonlinear dynamics approach (Sello, 2001), and a dynamical model of solar cycle (Orfila et al., 2002) were proposed to make a long-term forecast of the level of solar activity. Recently, a synthesis of solar cycle prediction techniques was given by Hathaway (1999). In this paper, a modified method, based on the previous method proposed by Li et al. (2002a), is developed to evaluate the level of solar activity at the remainder of a progressing solar cycle with the specific application to the level of sunspot numbers at the remainder of cycle 23.

2. The method to evaluate the level of long-term solar activity at the remainder of a progressing solar cycle

Since 1755, the beginning of the first recorded sunspot cycle, more than 22 sunspot cycles have passed, and fortunately a good record of sunspot numbers of 22 complete cycles has been archived. The smoothed monthly mean values of the sunspot numbers of cycle 1 to the present, which are provided by the Solar and Upper Atmosphere Group at the National Geophysical Data Center (see the web site http://www.ngdc.noaa.gov/stp/SOLAR/getdata.html), are used in this paper and displayed in Fig. 1. The figure shows that the present cycle, cycle 23, is now progressing and not yet completed.

Li et al. (2002a) had previously proposed a method to predict the relative sunspot numbers for the remainder of a progressing cycle using information from preceding cycles. The method involves determination of two parameters, the time shift, T, and the amplitude coefficient, C, which requires a large amount of computation. Here, we attempt to replace the time shift parameter by a fixed value representing conditions at sunspot minima. In this way, the method is modified to use only one instead of two parameters in order to reduce the amount of calculation. The last six complete cycles, cycles 17–22, are analyzed to demonstrate the efficiency of the modified method, and as an example, cycle 17 is employed to illustrate the method in details.

First, we move or match the smoothed monthly mean sunspot numbers of cycle 17 ($R^{17}(t)$) along the time axis toward those of cycle 1 ($R^{1}(t)$) until