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Application of the Grey Topological Theory in the Prediction of Yearly Mean Sunspot Numbers† ⋆

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Abstract The topological prediction theory of grey system is introduced in this paper, and the grey topological prediction model has been founded by using a series of smoothed yearly mean values of sunspot numbers from 1944 to 2008. Then this grey topological prediction model is applied to the prediction of the smoothed yearly mean sunspot numbers for the solar cycles 24, 25, and 26 from 2009 to 2039, respectively. The results indicate that the maximum values of sunspot numbers will most probably appear in 2014, 2023, and 2033, and the peak values are about 90, 110, and 130, respectively. And the predicted minimum values of about 20, 20, and 10 will occur around 2017, 2025, and 2039, respectively.

Key words sunspots—sun: activity–methods: statistical

1. INTRODUCTION

Solar activity has extremely closed relations with the human life, national economy, and national defence, the prediction of solar activity is the urgent necessity in many fields, such as the spaceflight, communication, electricity, navigation, meteorology, hydrology, and so on[1−4]. The prediction of solar activity is generally classified into the short-term prediction from several hour to several day in advance, the mid-term prediction of several month in advance, and the long-term prediction of several year in advance, and the content to be predicted includes the sunspot number, solar flare, solar radio flux, solar proton event,

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coronal mass ejection, and other solar activity phenomena[5]. Among these solar activity phenomena, the sunspot number is most easy to be observed, and closely related with other activity phenomena, the long-term prediction of solar activity indicates mainly the prediction on the overall solar activity level represented by the monthly or yearly mean values of relative sunspot numbers, especially the predictions on the maximum and minimum values of relative sunspot numbers, and the time of their occurrence[6].

The long-term prediction of relative sunspot numbers is always a difficult topic in the research of long-term prediction of solar activity, many authors in the world have developed various prediction methods in their practice of long-term prediction of sunspot numbers, and obtained many good results. At present, the common-used methods of sunspot prediction are the time-series method, the parametric method of activity cycle, autoregressive model, long-period method, neural network prediction method, precursor method, etc.[5]. Besides the precursor method, these methods are all based on the data of previous sunspot numbers, which contain the basic information of future sunspot numbers, as well as the statistical regularity of the long-term variation of the sunspot number, and they are widely used up to now. But these methods generally need a large number of history data to establish a statistical model, and in the modeling the selection of parameters will unavoidably have certain subjectivity and empiricism. Not based on the statistical regularity, the precursor method, such as the solar activity precursor method and earth parameter precursor method, considers that the sunspot activity is strongly correlated with the solar magnetic activity parameter and geophysical parameter, taking these parameters as the prediction factors the maximum and minimum sunspot numbers can be derived. This method has performed rather well in the 21th and 22th solar cycles, but the predicted time is generally limited in one solar cycle. Because of the uncertainty of the physical process of the long-term variation of solar activity, and the very limited information available, to make the long-term prediction on the sunspot activity is very difficult.

The grey prediction theory developed in recent years provides a new idea for the long-term prediction of sunspot numbers. From the random, disorderly, and unsystematic data, the grey prediction looks for the intrinsic regularity hidden in the data, it has solved many practical problems, and achieved significant successes in the society, meteorology, hydrology, economy, power source, and other fields[8]. The traditional method of probability and statistics requires a large number of sample data, otherwise the statistical regularity can hardly be found, however the grey prediction theory has no strict requirement on the number and regularity of the sample data, it especially suits for the indefinite system with the unclear physical type and insufficient information that can hardly be treated by the probability and statistics theory[9], for example the solar activity. The common-used grey prediction model GM(1,1) has a good effect for the simple exponential curve, the yearly mean value of relative sunspot numbers varies irregularly, to predict the sunspot number by using directly the GM(1,1) model can hardly obtain an ideal result, for the data with large and frequent