Chin. J. Astron. Astrophys. Vol. 2 (2002), No. 5, 396–398
(http://www.chjaa.org or http://chjaa.bao.ac.cn)

Chinese Journal of Astronomy and Astrophysics

LETTERS

Verification of a Similar Cycle Prediction for the Ascending and Peak Phases of Solar Cycle 23

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Received 2002 July 18; accepted 2002 July 28

Abstract Reviews of long-term predictions of solar cycles have shown that a precise prediction with a lead time of 2 years or more of a solar cycle remains an unsolved problem. We used a simple method, the method of similar cycles, to make long-term predictions of not only the maximum amplitude but also the smoothed monthly mean sunspot number for every month of Solar Cycle 23. We verify and compare our prediction with the latest available observational results.

Key words: Sun: sunspots — solar-terrestrial relations

1 INTRODUCTION

Reviews of long-term solar cycle predictions made by Brown (1986) for Solar Cycle 21, Kunches (1993) for Solar Cycle 22 and Wang et al. (2002) for Solar Cycle 23, respectively, have shown that much progress has been made in this field since the 60s, but so far no methods have been found to give good predictions for all the recent solar cycles, Cycles 20 through 23. Although it was thought that methods based on observed precursors were retained for operational purposes, the precursor technique is the only one that has met the approval of the majority of the scientific community.

It has been known for a long time that many prediction users in different fields require not only the prediction of the maximum amplitude of the solar cycle but also that of the smoothed monthly mean sunspot number (hereafter SMMSN) for every month of that cycle. The precision of prediction is still far below what the users require, and some users need a lead time of more than 2 years. To satisfy the requirements of such users, we have developed a simple method based on the concept of similar cycles. We have applied it to predict the SMMSNs of Solar Cycle 23 (Wang & Han 1997). In the second part of the present paper, we first give a simple introduction to the method, then a verification of the predictions. The method and verification are then discussed in the last part.

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2 METHOD AND VERIFICATION

The conception of similarity or homology used in solar activity studies is basically of morphological meaning. Here similar cycles are defined as those cycles whose parameters are in a common range and whose SMMSN time profiles are similar in shape.

To select solar cycles that are similar to Solar Cycle 23, we first collected for Cycle 23, all the predictions of parameters (the beginning minimum, duration of ascending phase, and maximum amplitude) and built a synthesised parameter set. We then compared it to the parameter sets of Solar Cycles 1 to 22 and we also compared the time profiles of Cycle 1 to 22 with each other by superposition. In this way, we found Cycles 8, 9, 11, 17, 18, 20 and 21 to be "similar" to Cycle 23 (see table 1 in Wang & Han 1997). We then took the average of the SMMSNs of the similar cycles for the beginning month as the predicted SMMSN for the beginning month of Cycle 23, their average SMMSN for the second month as the predicted SMMSN for the second month of Cycle 23, and so on. The standard deviation of the SMMSNs of the similar cycles for a given month to the average SMMSN of the same month was then taken as the estimate of the error of prediction for that month. As a verification of our predictions, Figure 1 confronts our predicted SMMSNs for the ascending and peak phases of Solar Cycle 23 with the observed data.

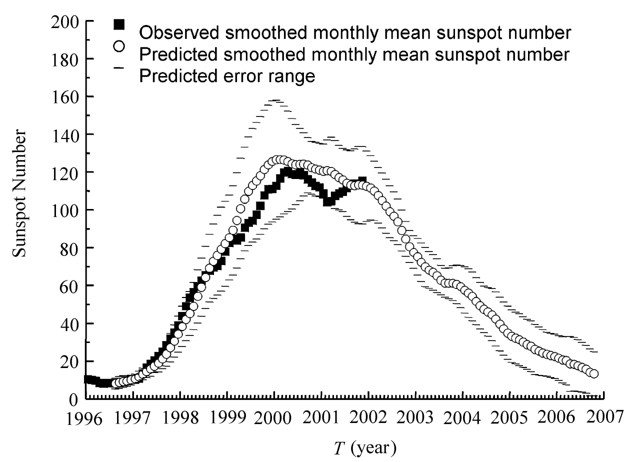

Fig. 1 Comparison of the predicted (circles) and observed (filled squares) SMMSNs. Error of prediction indicated by short bars.

One may see from Figure 1 that the prediction agrees well with the observation, at least for the ascending and peak phases. In particular, for the first half of the ascending phase including the peak, the method of similar cycles seems applicable as a long-term prediction of the maximum amplitude and the SMMSNs.

3 DISCUSSION

1. The verification of our prediction for Cycle 23 suggests that our method of similar cycles can be used in practice pending the necessary theoretical and/or statistical improvement.

Usable predictions of SMMSNs can thereby be provided to users, at least, for the months of the ascending and peak phases of a cycle.

2. When applying the method of similar cycles, the question as to which cycles are to be regarded as similar to the given cycle is obviously of key importance. When we use a stricter condition for the selection, fewer cycles will be selected, the calculating error will be less, but, on the other hand, the involved risk will be greater. In the contrary case, when there are more cycles selected, the error will be greater while the risk will be less. In our experience, the optimal number of similar cycles should be 5 or 6.

3. Some methods which were used recently and might give good predictions for Cycle 23 will have to wait for a long time before they can be generally accepted as successful.

4. It has been known that the time sequence of the SMMSN is chaotic (e.g. Farmer & Sidorowich1987; Mundt et al. 1991; Ma & Wang 1996). It seems to be impossible to make a precise long-term prediction of the SMMSN for a certain month by analysing the SMMSN time sequence, because the relation between the prediction errors of a given month and the preceding months is non-linear. As we know, some long-term predictions of the SMMSN show that the error of prediction increases as the lead time of the prediction increases and that for a long lead time the error of the prediction could be quite large. In contrast, the prediction error in our similar cycle method is not affected by the chaotic character of the SMMSN time sequence because our predictions for the individual months of the given cycle are made in one go, not one after the other.

Acknowledgements This work was supported by the National Natural Science Foundation of China (Grant Nos. 4999–0451 and 10073013) and Space Environment Forecast Center, CSSAR, CAS.

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