DEPENDENCE OF SSN_M ON SSN_m – A RECONSIDERATION FOR PREDICTING THE AMPLITUDE OF A SUNSPOT CYCLE

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Abstract. An improved correlation between maximum sunspot number (SSN_M) and the preceding minimum (SSN_m) is reported when the monthly mean sunspot numbers are smoothed with a 13-month running window. This relation allows prediction of the amplitude of a sunspot cycle by making use of the sunspot data alone. The estimated smoothed maximum sunspot number (126 $\pm$ 26) and time of maximum epoch (second half of 2000) of cycle 23 are in good agreement with the predictions made by some of the precursor methods.

1. Introduction

Solar activity affects the near-Earth environment that can influence the performance and reliability of space-borne and ground-based technological systems. In this perspective it is important to know beforehand the amplitude of the solar activity in a solar cycle. Many schemes have been employed to predict the amplitude of the current cycle (Cycle 23) and have been nicely reviewed by Lantos and Richard (1998). Wilson (1990) has made a comparison between single variable analysis (e.g., SSN_M versus $aa_{\min}$) and bivariate analysis (e.g., SSN_M versus $aa_{\min}$ and SSN_m) and indicated that the bivariate methods performed well in estimating the amplitude of a sunspot cycle. Kane (1992) indicated that the correlation between SSN_M with SSN_m is only $+0.27$ and does not serve as a good predictor of the peak of the sunspot cycle although SSN_M correlates well with SSN_m for helio latitudes $20°–40°$ (Kane and Trivedi, 1980). Brown (1976), however, opined that the progression to the maximum of a given solar cycle is determined in amplitude and probably in phase by the conditions prevailing at the preceding minimum of the cycle. In this short communication we try to review this possibility wherein the predictions can be made possible self-consistently using the sunspot data alone.

2. Analysis and Results

Kane (1978) used only 9 solar cycles data to obtain a correlation of +0.27 between SSN_M and SSN_m. We now know that the solar activity cycle is highly variable (see, Zwaan, 1987), even from cycle to cycle. In such a situation the low statistics

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obviously cannot establish a good relation between the two parameters. Here we use monthly mean sunspot data for 22 cycles (see McKinnon, 1987; for the quality of the data) to establish a reasonably good relation between SSN_M and SSN_m.

Figure 1a depicts the relation between the SSN_M and the SSN_m obtained from the 13 month running averages of monthly mean sunspot numbers. Number of data points (N) and the correlation coefficients (γ) are also shown in the Figure 1. The correlation, though weak, is significant at the 99% level of confidence. The regression equation is given by

$$\mathrm{SSN}_M = 76.26 + 6.18\ \mathrm{SSN}_m\ . \tag{1}$$

Figure 1(b) shows the scatter plot of duration of the ascending phase of the cycle (T_A) against the cycle maximum (SSN_M). As indicated by Brown (1976) and Kane (1978), a reasonably good correlation is seen. A second order polynomial fit seems to be a best fit and the regression equation is given by

$$T_A = 112.92 - 0.85\ \mathrm{SSN}_M + 0.00258\ \mathrm{SSN}_M^2\ . \tag{2}$$

Using $\mathrm{SSN}_m = 8.1$ (13 month smoothed minimum of the beginning of the cycle 23) in Equation (1), the predicted smoothed sunspot number (SSN_M) is given by 126 ± 26. The deviation $\pm$ 26 is the average of the deviations from the observed to the fitted values. Using $\mathrm{SSN}_M = 126$ in Equation (2) gives a duration of the ascending phase of the cycle 23 as 46 ± 6 months.

The advantage of using 13-month-running averages of monthly mean values of sunspot numbers is to get a reliable estimation of the duration of the ascending phase of the cycle. Otherwise the prediction of SSN_M (120 ± 25) is still valid when a similar relation is obtained with the yearly averages of the sunspot numbers, the regression of which is given by

$$\mathrm{SSN}_M = 67.9 + 6.09\ \mathrm{SSN}_m \tag{3}$$

with a correlation coefficient of 0.585 (99% confidence). The expected maximum epoch using August 1996 as the minimum ($\mathrm{SSN}_m = 8.1$) period of the beginning of cycle 23 is estimated to be during June – November, 2000.

These estimated parameters of cycle 23 are comparable with the predictions of Kane (1999), Mendoza and Ramirez (1999), Schatten, Myers, and Sofia (1996), and Ahluwalia (1998), though are underestimates compared to the predictions (160 $\pm$ 20) made by the scientific panel of solar cycle 23 project (Joselyn *et al.*, 1997) and many others (see Lantos and Richard, 1998, and references therein).

Limitations with this method prevail. As in the other precursor methods the predictions can be made only a year after the beginning of the cycle. As to errors, though comparable with the ones estimated with the other methods, they are high and the reliability of the method may improve further with the improved statistics.

If this method works well for prediction purposes, then it will have implications on the control of average minimum flux prevailing at the beginning of the cycle on

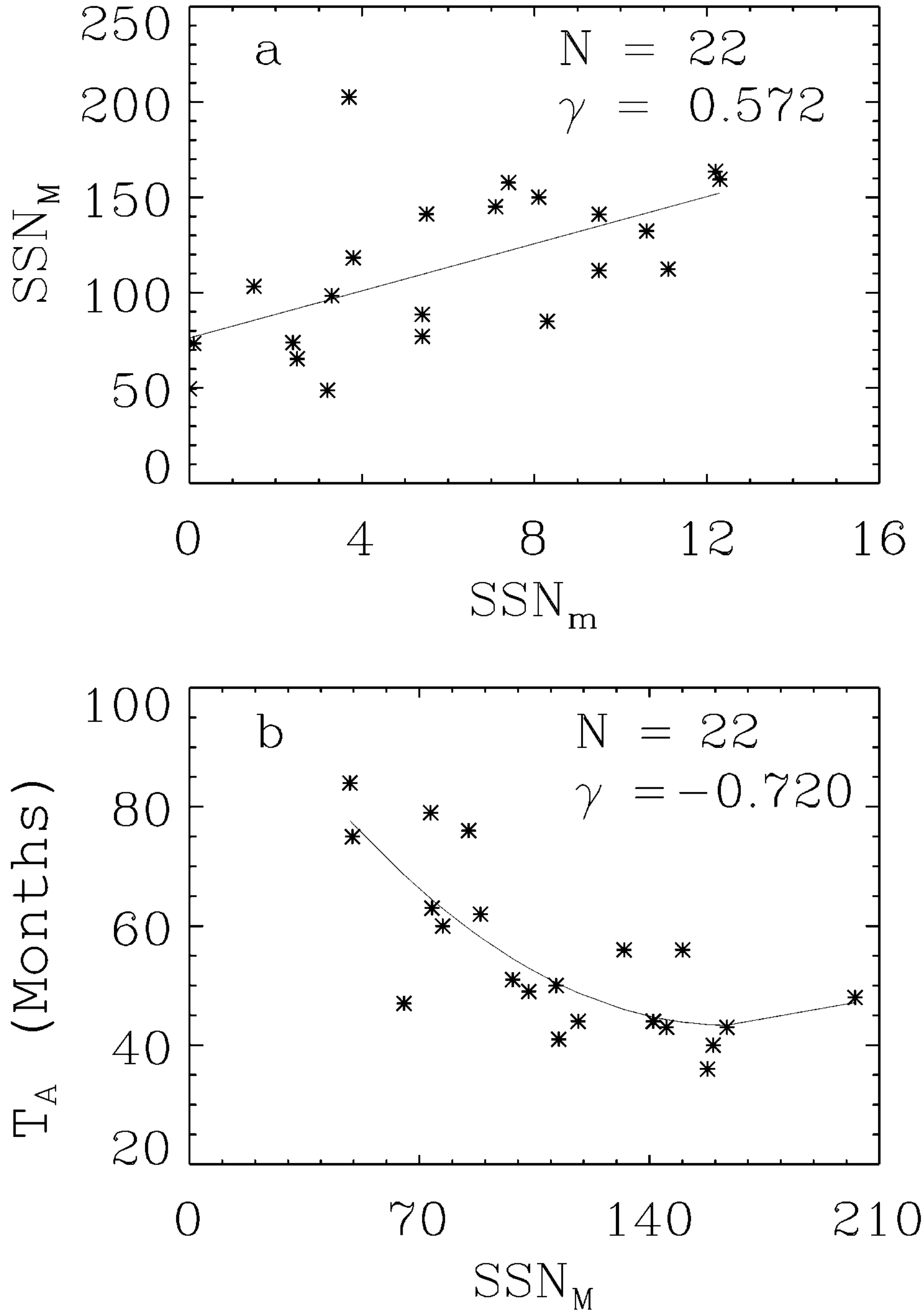

Figure 1. (a) Sunspot number (SSN_M) at maximum epoch plotted against the sunspot number (SSN_m) at the epoch of preceding minimum. (b) Duration (T_A) of the ascending phase of the cycle is plotted against the sunspot number (SSN_M) at the epoch of cycle maximum.

the peak flux emergence during the epoch of sunspot activity maximum as indicated by Brown (1976). This would also support the aim of De Toma, White, and Harvey (2000) who intend to study the influence of the patterns in the emergence of surface magnetic fields during solar minimum on the activity during the epoch of solar maximum.

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