A PREDICTION FOR SUNSPOT CYCLE TWENTY-TWO

PETER O. TAYLOR
P. O. Box 8115
Gainesville, FL 32605

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Abstract

A prediction for the maximum of sunspot cycle 22 and a comparison of this result with similar predictions based on a variety of techniques are presented.

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Since the suggestion of periodicity in the numbers of sunspots by the 18th century Danish astronomer, Christian Horrebow (Thiele 1859), solar investigators have devised various ways to predict the strengths and epochs of cycle maxima. The methods that are most often employed attempt to establish correlations between these parameters and the behavior of past sunspot cycles, other solar and geomagnetic indices, or the effects of long-term secondary and tertiary cycles.

Table I is a sampling of the many predictions that have been proposed for the current cycle, number 22 in the Zurich numbering system. The techniques vary considerably.

The McNish-Lincoln procedure (McNish-Lincoln 1949) is closely related to regression methods; that is, current and past cycles are compared analytically. This process is most reliable for predictions up to 12 months in advance. Tabular values reflect the latest analysis available to us (Anon. 1988).

Wilson (1984) used secular methods for his evaluation. This procedure projects future cycle activity as it may be influenced by the existence of long-term periodicities such as the Gleissberg 80-year cycle (Gleissberg 1952). Auto-correlation and power spectrum analyses are frequently exploited in this method.

Koeckelenbergh (1988b) derived his result through an analysis based on normalized sunspot-cycle curves primarily determined by Waldmeier (1968; 1976) and that point in time where the current cycle's smoothed monthly mean equals or exceeds a value of 50 on the ascending branch.

The method of Sargent (1977; 1978) ties the intensity of maximum to the sunspot number at minimum and to the geomagnetic aa index through regression analysis.

Kane (1978; 1987) utilized similar but simpler means that correlate maximum intensity directly with the minimum annual aa index during the years immediately preceding maximum.

NASA Marshall Space Flight Center scientists compared the current cycle with previous cycles (Anon. 1987) but employed a data-base consisting of monthly mean 10-cm radio flux values. The results were then converted to their comparable sunspot number.

Individual cycles are quite variable: Waldmeier (1961; 1976) and Koeckelenbergh (1988b) have shown that maxima since 1700 have ranged in strength from smoothed mean values of ~48 to slightly over 200, while cycle lengths have varied between 7 and 17 years, with an average near 11 years. It is generally agreed (i.e., Brunner in Shapley 1944) that the rate of rise to maximum is highest for cycles of greatest intensity; thus, cycles that display maxima of high sunspot number have shapes that are noticeably more asymmetrical than those that peak at lower levels (e.g., Koeckelenbergh 1988b).

Sunspot cycles during the last few decades have generally developed maxima of higher intensity than those recorded previously. For example, cycle 19 became the greatest on record when it attained a smoothed sunspot number of 201, and cycle 21 (with a mean at maximum near 165) is second strongest. The maximum sunspot number for cycle 18 was slightly lower, but also surpassed 150. Only one additional cycle (cycle 3) has equaled or exceeded a value of 150 since 1700, and if Schove (1983) is correct in the extrapolation of auroral and inferred sunspot data, the period could be extended back to the beginning of the 16th century and perhaps before.

At this time, the rate of rise in the numbers of sunspots for cycle 22 is considered to be very rapid. In addition, a number of other solar activity indices (for example, the 10-cm radio flux and the migration of certain solar magnetic phenomena towards the Sun's poles) also show evidence of higher than normal rise rates.

In light of the recent performance of the sunspot cycle, and of the rise-rate implications that indicate an upcoming maximum that may also exceed 150, we have prepared a graphical analysis that compares the ascending branch of the current cycle as it has been recorded thus far with the completed rise phases of cycles 18, 19, and 21. Cycle 20, of much lower intensity than the others, was considered separately.

Due to the time span under consideration in our analysis, we have utilized Zurich and International smoothed monthly mean sunspot numbers rather than the newer American values. The data were provided in Waldmeier (1961; 1976; 1976-1979) and in Koeckelenbergh (1980-1987; 1988a).

The procedure that we followed was a simple one. First we fit the rising leg of the current cycle to the ascending branches of the comparison cycles, individually. In each case, the best fit (in the least-squares sense) was obtained through the use of a small computer and simple program that effectively phase-shifted the current cycle in relation to each of the others.

During early stages of the rise-phase, the rate of ascent described by the most recent monthly means is more meaningful than earlier values. Thus, when implementing the reduction process, we weighted the latest mean values higher than those at cycle onset.

This procedure produced a relative time of ascent, extending from the onset of cycle 22 to a projected maximum for each of the cycles. We then computed the average of these times, and obtained their mean maximum-intensity. A predicted date for the epoch of maximum for cycle 22 was obtained by adding the average rise time to the date of cycle onset (1986.75). Probable errors for this determination and for the normalized intensity at maximum were computed from statistical evaluations of the differences between the comparison cycles.

We find that the maximum of cycle 22 will occur 1990.0 $\pm$0.1 with a mean intensity of 173 $\pm$17. For purposes of comparison, our result is also included in Table I.

Finally, the derived ascending branches were subjected to an equally-weighted averaging process and a normalized branch was computed. Predictions for smoothed mean sunspot numbers were taken directly from this branch for each monthly interval, and the error for each, based on a vertical shifting of the branches relative to the normal branch, was estimated as a percent of each value. The results are provided in Table II, and illustrated in Figure 1.

A number of the predictions for this cycle have been generated in terms of high-intensity maxima. However, at this early phase of development (14 months into the new cycle) the fit obtained for the rising leg of cycle 22 and the ascending phase of cycle 20 is as good or better statistically than that of the others when our generalized technique is employed. A number of other methods do not share this probable limitation, and it appears that the likelihood of a maximum in the range of the intensity of cycle 20 (a smoothed mean of ~110) is not high. The relationship of cycle 20 to the mean branch after least-squares fitting according to the graphical technique is also shown in Figure 1.

For cycles that attain smoothed maxima of less than 150, methods that employ parameters determined from a number of previous cycles should certainly give more consistent results than this method. On the other hand, very little information is available on the development of the highest intensity cycles, and this technique, or those that employ other indices such as the aa index, may prove to be more satisfactory for these applications.

The large variation between sunspot cycles dictates that predictions for their maxima be regarded with some caution. However, our results do agree quite well with those of Kane, Koeckelenbergh, and the Marshall group, each derived by considerably different methods.

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TABLE I

Recent Predictions for Sunspot Cycle 22

Reference	Intensity	Date
McNish-Lincoln	198 ±67	1989.9
Wilson	107	1991
Koeckelenbergh	170 ±25	1989.8
Sargent	119	1991
Kane	185 ±40	1988-89
Marshall Space Flight Center	173	1990
Taylor	173 ±17	1990.0 ±0.1

TABLE II

Predicted Smoothed Monthly Mean Sunspot Numbers

Month	Number	Error	Month	Number	Error
Dec 1987	51	±5[d]			
Jan 1988	56	6	Jan 1989	124	±12[d]
Feb 1988	60	6	Feb 1989	130	13
Mar 1988	67	7	Mar 1989	135	14
Apr 1988	74	7	Apr 1989	139	14
May 1988	81	8	May 1989	144	14
Jun 1988	87	9	Jun 1989	151	15
Jul 1988	94	9	Jul 1989	156	16
Aug 1988	101	10	Aug 1989	160	16
Sep 1988	107	11	Sep 1989	163	16
Oct 1988	111	11	Oct 1989	166	17
Nov 1988	115	12	Nov 1989	170	17
Dec 1988	118	12	Dec 1989	173	17

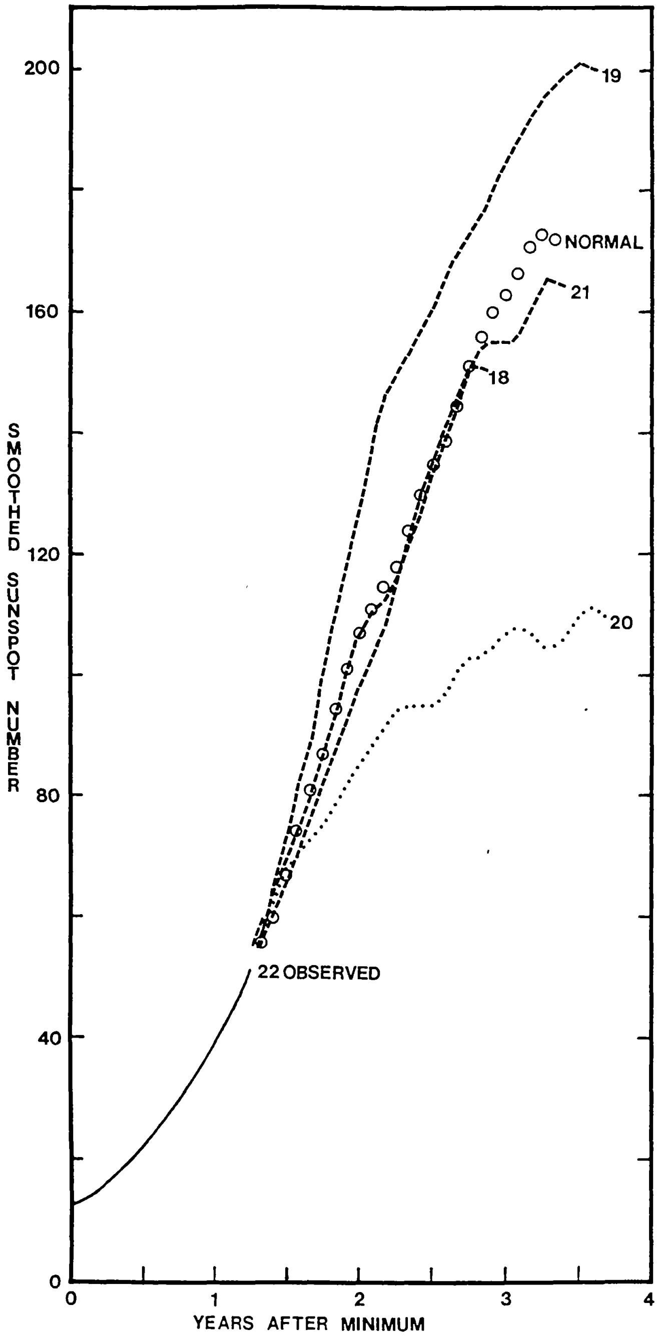

Figure 1. The proposed normalized ascending branch for sunspot cycle 22, and similar phases of cycles 18, 19, and 21 after each has been fitted to the observed branch of cycle 22 according to techniques described in the text. While cycle 20 was not included in the analysis, its progress is shown after a similar fitting process. (--) 18; (--) 19; (..) 20; (--) 21; (__) 22 observed; (O) normalized.