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Prediction of maximum amplitude of the next Solar Cycle 24 Using Precursor method

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For predicting the maximum amplitude of forthcoming solar cycle 24, precursor method is used. The study uses R12 and the number of geomagnetic disturbed days in a month during the last seven cycles. The technique uses second-degree correlations coefficients between Geomagnetic Disturbance Index (DI) at ten selected times during the decline part of a solar cycle with maximum R12 of the ensuing solar cycle. Correlation of DI averages of the best three cases in each cycle gives correlation with peak R12 values equal to 0.99 and back predicted values comes within 2-3 % of the observed R12 peaks and predict a maximum amplitude of R12=140 for the forthcoming solar cycle 24.

Introduction:

Solar activity forecasting is important for various scientific and technological applications, like operations of low-Earth orbiting satellites, electric power transmission lines, high frequency radio communications and geophysical applications. Solar cycle is very difficult to predict on the basis of time series of various proposed indicators, due to high frequency content, noise contamination, high dispersion level and high variability both in phase and amplitude, with intermittent behavior at different scales. This topic is also complicated by the lack of a quantitative theoretical model of the Sun's magnetic cycle. Various techniques for solar cycle forecasting are developed to accurately predict phase and amplitude of future solar cycles, but with limited success. Depending on the nature of the prediction methods, one can classified them into five main categories namely: Curve fitting; Precursor; Spectral; Neural Networks and Climatology. But only the precursor technique has won approval from the scientific community. This technique works on the notion that the solar cycle begins some years before solar minimum with the appearance of long-lived, coronal holes, which give rise to sequences of 27-day recurrent geomagnetic disturbances. Many applications of the precursor method use the long record of geomagnetic disturbances to correlate their occurrence with the amplitude of the next solar cycle. Richard Thompson (1993) who found a relationship between the number of days during a sunspot cycle in which the geomagnetic field was "disturbed" and the amplitude of the next sunspot maximum. His method has the advantage of giving a prediction for the size of the next sunspot maximum well before sunspot minimum. Shastri (1998) also successfully uses the precursor method for estimating the peak of the solar cycle 23 using multivariate analysis technique. In the present study, a modified precursor method is used for predicting the maximum amplitude of forthcoming solar cycle number 24.

Results and Discussion

The modified precursor technique uses the frequencies of geomagnetic disturbances (as precursors) evaluated at ten equal interval of time during the declining phase of a solar cycle. In the present study, twelve monthly running average sunspot number (R12) and the number of geomagnetic disturbed days in a month as defined by Thompson (1987) with Ap values more than or equal to 25, for the periods corresponding to last seven solar cycles number 17 to 23 are considered. Geomagnetic disturbance index (DI) is determined using 12 month moving average of the monthly geomagnetic disturbed days. Figure 1 shows the temporal behaviors of twelve monthly smoothed sunspot numbers R12 and disturbance index DI for the last seven sunspot cycles numbers 17-23. To better describe the behavior of DI during the declining part of each solar cycle, ten equally spaced points (roughly at after every six months starting from R12 peak value) after the peak R12 are examined which are hereafter referred to as variate 1, 2,…10. Then best of the first and second-degree correlations coefficients (CC) are obtained between DI at ten (equal-spaced) selected times (variates) during the decline part of a solar cycle and the R12 maximum of the ensuing solar cycle to predict back the observed R12 peak values for cycles 17-23. Table 1 shows first degree Regression Results of Running average of observed R12 and DI at each variate point. Further from the above ten variates results (see table 1) we selected those with CC more than 0.75 namely 5, 9 and 10 and then for these cases second degree correlations coefficients are obtained which results in better CC as compared to first degree results as shown in figure 2 and table 2. In general, second-degree correlation coefficients gives better results and the predicted values agree within 5 to 10 percent of the observed R12 peak values for cycles 17-23 as shown in table 3. Instead, in each cycle if we take average of the best three second degree cases DI's i.e. variate number 5, 9 and 10 and again determine their correlation with peak R12 values which gives correlation coefficients as high as 0.99 and predicted values reaches within 2-3 % of the observed R12 peaks for cycles 17-23. The present technique predict a maximum amplitude of about R12=140 for the forthcoming solar cycle number 24 (see table 3).

References

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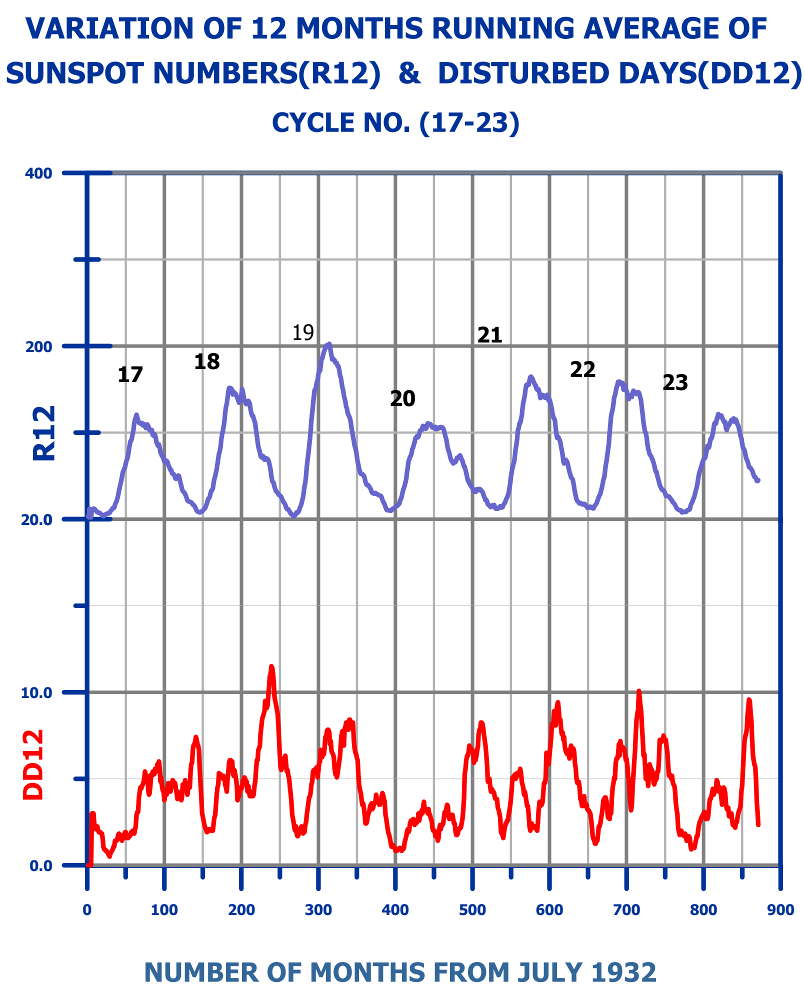

Figure 1. Shows the temporal behaviors of twelve monthly smoothed sunspot numbers R12 and disturbance index DI for the last seven sunspot cycles numbers 17-23.

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COMPARISON OF FIRST AND SECOND DEGREE FIT

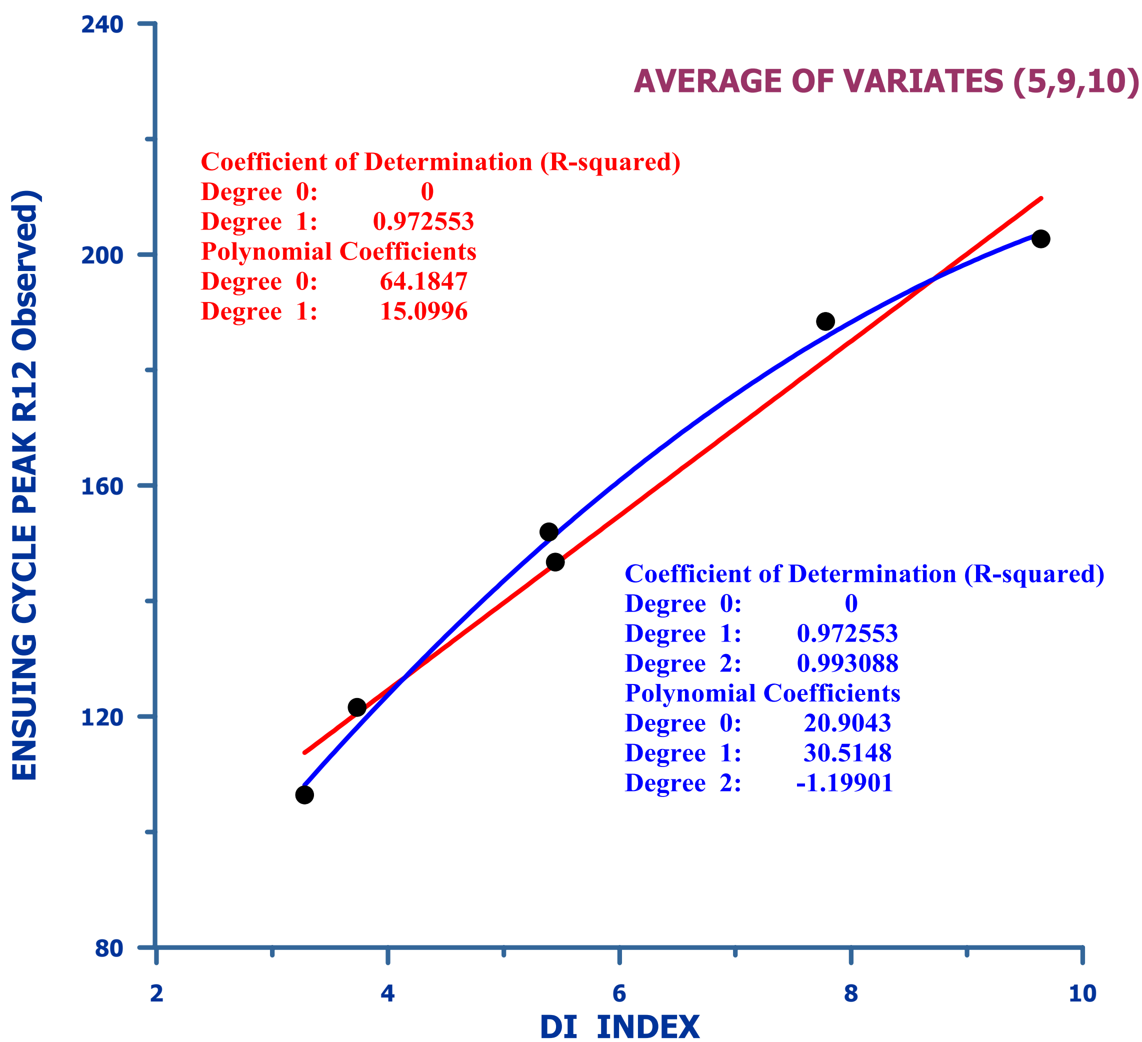

Figure 2. The first and second-degree correlations coefficients obtained between average DI of 5, 9 & 10 Variates during the decline part of a solar cycle with the R12 maximum of the ensuing solar cycle for cycles 17-23.

Table 1. Linear Regression Results of Running average of Observed R12 and DI at each variate point. DI Index = Number of days in a month $(Ap \geq 25)$

	R^2 (correlatio coefficient) ^{2}	S.E for linear fit	Coefficient Degree 0	Coefficient Degree 1
Variate No 1	0.22	6.56	188.20	-7.02
Variate No 2	0.40	7.97	212.51	-13.07
Variate No 3	0.43	9.05	228.11	-16.01
Variate No 4	0.62	5.61	227.99	-14.18
Variate No 5	0.78	3.73	69.61	14.18
Variate No 6	0.43	11.63	16.95	20.23
Variate No 7	0.64	5.35	69.30	14.30
Variate No 8	0.73	4.32	69.96	14.50
Variate No 9	0.83	2.47	81.40	11.18
Variate No 10	0.80	3.10	84.32	12.79
Average (5,9,10)	0.97	1.26	64.18	15.10

Table 2. Second Degree Regression Results of Running average of Observed R12 and DI at best linear fits

	R^2 (First deg.)	R^2 (Second Deg.)	Coefficient Degree 0	Coefficient Degree 1	Coefficient Degree 2
Variate No 5	0.78	0.82	131.7	-11.6	2.3
Variate No 9	0.84	0.86	43.1	23.4	-0.8
Variate No 10	0.81	0.83	102.7	4.6	0.7
Average (5,9,10)	0.97	0.99	20.9	30.5	-1.2

Table 3. Hind cast Results using Second degree fit

CYCLE	Observed Peak	Variate 5	Variate 9	Variate 10	Average (5,9&10)
18	151.9	168.0	127.7	140.3	150.5
19	202.7	189.8	203.8	208.8	203.6
20	106.4	117.0	114.9	129.5	108.0
21	188.4	189.8	180.4	170.0	185.7
22	146.7	121.9	159.5	155.9	151.5
23	121.5	130.9	131.0	112.9	118.1
24	Predicted	124.4	139.6	144.2	139.3