NRIAG Journal of Astronomy and Geophysics xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

NRIAG Journal of Astronomy and Geophysics

journal homepage: www.elsevier.com/locate/nrjag

Full length article

Forecasting the peak of the present solar activity cycle 24

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ARTICLE INFO

Keywords:
Solar activity cycle
Spotless events
Solar flux F10.7
Geomagnetic index aa_{min}

ABSTRACT

Solar forecasting of the level of sun Activity is very important subject for all space programs. Most predictions are based on the physical conditions prevailing at or before the solar cycle minimum preceding the maximum in question. Our aim is to predict the maximum peak of cycle 24 using precursor techniques in particular those using spotless event, geomagnetic $aa_{min.}$ index and solar flux F10.7. Also prediction of exact date of the maximum (T_r) is taken in consideration. A study of variation over previous spotless event for cycles 7–23 and that for even cycles (8–22) are carried out for the prediction. Linear correlation between maximum of solar cycles (R_M) and spotless event around the preceding minimum gives $R_{24t} = 88.4$ with rise time $T_r = 4.6$ years. For the even cycles $R_{24E} = 77.9$ with rise time $T_r = 4.5$ y's. Based on the average $aa_{min.}$ index for cycles (12–23), we estimate the expected amplitude for cycle 24 to be $R_{aamin} = 99.4$ and 98.1 with time rise of $T_{raamin} = 4.04$ & 4.3 years for both the total and even cycles in consecutive. The application of the data of solar flux F10.7 which cover only cycles (19–23) was taken in consideration and gives predicted maximum amplitude $R_{24\ 10.7} = 126$ with rise time $T_{r107} = 3.7$ years, which are over estimation. Our result indicating to somewhat weaker of cycle 24 as compared to cycles 21–23.

1. Introduction

It is well known that solar activity variations control the disturbance in space weather, variation in the climatic parameters as well as the most activity on the Earth. Long term recorded aspect of the solar activity in all the astrophysical ones are that of sunspots which have been observed since 1610. It's cyclic behavior was noticed by Schwabe (1844). The sunspot number Rz (Wolf number) is widely used in solar terrestrial physics as a proxy for general state of solar activity when daily averaged are frequently available (Hoyt and Schatten, 1998a,b). Their number in time interval may in one way or another represent an index of general solar magnetic activity (Eddy, 1976, 1977, Hoyt and Schatten, 1997, 1998a,b).

The maximum phase of activity cause higher emission of the ultraviolet UV and UV flux, which can modulate the middle and upper terrestrial atmosphere and total solar irradiance which have effect on terrestrial climate (Hoyt and Schatten, 1997). Also the occurrence of large solar flare during the maximum phase of activity associated with energetic particles cause communication disturbance and failures in electronic solid state components etc. (Siscoe, 2000).

All these facts justify the scientific and practical importance of predicting the strength of the upcoming solar cycles. During the past decade numerous techniques have been arduously developed and proposed by many scientific researchers to predict the amplitude, the phase of activity and the maximum strength of the fourth coming cycles.

Different approaches were used to achieve a good forecasting of the level of the next cycle in which features of the preceding cycle are used for this purpose (Kane, 2011, Ajabashirizadeh et al., 2011, Du, 2012). Among these are methods depend on odd/even behavior (Kopecky, 1991, Wilson, 1992, Letfus, 1993, Kane, 1999), the mixed methods (Wilson et al., 1998, Hanslmeier et al., 1999, Hathaway et al., 1999, Lantos, 2000) and spectral technique (Badalyn et al., 2001, AShrafi and Roszman, 1992, Volobuev and Makarenko, 2008). Precursor technique characterized by both solar and geomagnetic as their physical basis, and geomagnetic precursor based on the records of the geomagnetic storms i.e. the indices of aa, Ap or both of them (Boinar et al., 1997, Rajmal, 1997, Joselyn et al., 1997, Kane, 2007, Thompson, 2008) have been used. Another category of the precursors are solar polar magnetic field (Tlatov, 2006) and precursor based on the records of spotless days along two years around the preceding minimum of cycle under test (Hamid and Galal, 1994, Hamid, 2000).

A promising method depends on the time analysis, as neural network, fuzzy neural network and genetic algorithms derived from nonlinear statistical algorithms that determine and model a complex relationship between inputs and outputs. It can be combined with other

Peer review under responsibility of National Research Institute of Astronomy and Geophysics.
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https://doi.org/10.1016/j.nrjag.2018.02.002
Received 16 November 2017; Received in revised form 31 January 2018; Accepted 7 February 2018

Please cite this article as: Hamid, R.H., NRIAG Journal of Astronomy and Geophysics (2018), https://doi.org/10.1016/j.nrjag.2018.02.002

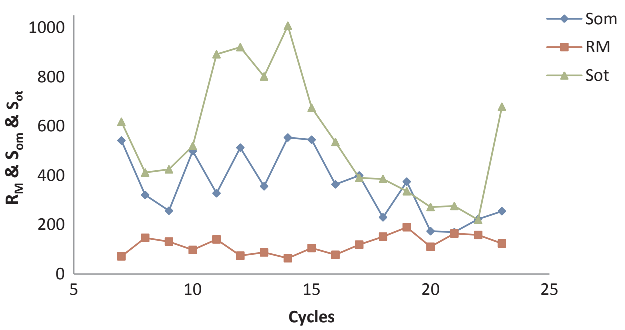

Fig. 2.1. The maximum number of solar cycles R_M, the total spotless event S_{ot} and precursor spotless events S_{om} against solar cycle (7–23).

technique including spectral methods to increase the accuracy (Calvo et al., 1995, Lantos, 2000, Attia et al., 2005).

According to Janssens (2006) and Pesnell (2008) another suggested categories have been approved which are climatology, recent climatology and dynamo methods.

2. Data sets

2.1. Spotless Events

Since we depend in our precursor method on the count of spotless event in interval of two years around the minimum of each cycles starting from solar cycle 7 up to minimum of cycle 24, it was found that total number of this count is 6567 days out of the total observing data of 70795 days. The data set was taken from http://NGDC.noaa.gov/stp/solar/sunspot_numbers/internation.

We noticed that as the number of spotless events around the preceding minimum increase, the solar cycle achieve a low level of strength and vice versa. Fig. 2.1 illustrates solar cycles (7–23) versus the total spotless events S_{ot} along each cycle, the precursor spotless events S_{omn} (around the preceding minimum), and the maximum sunspots number of each cycle R_M.

2.2. Geomagnetic index aa

The aa-index is a simple global geomagnetic activity index. It is derived from the K indices from two approximately antipodal observatories and has units of 1nT. The main advantage of using aa index is that the time series spans further back to (1868) than any of the other planetary index time series; and also up to data values are produced and made available on weekly basis. Definitive aa are published by International Series for Geomagnetic Indices (ISGI).

2.3. Flux F10.7

Another indicator of the level of solar activity is the flux of radio emission from the sun at wavelength 10.7 cm (2.8 GHz frequency). It is one of the popular substitution of R_z. The advantage of F10.7 is its immediate availability. The values of F10.7 always measured within hours while the definitive of R_z is always delayed by month. It is an important indicator of solar activity level because it tends to follow the change in solar ultraviolet (UV) that influence the earth's upper atmosphere. It has been measured since 1947 and it follows sunspot number. Current values of F10.7 can be found at ftp://ftp.ngdc.noaa.gov/stp/solar_data/solar/flux/pentiction.

Fig. 2.2 illustrates the comparison between number of sunspots, geomagnetic index aa and solar flux F10.7. it is clear that the three variables have the same trend of variations.

3. Analysis

The statistical approaches are important process to detect our calculation of the strength of solar cycle number 24.

3.1. Forecasting the peak of the solar cycle 24 using Spotless events

To carry out the predicted count of spotless events at the minimum of the upcoming cycle in advance, we first use the following logarithmic empirical formula (Eq. (1)), so it is easy to estimate the maximum phase of the next cycle (Hamid and Galal, 2006).

$$\ln\left(\frac{R_M}{R_m}\right) = a + b\left(\frac{S_{om}}{S_{omn}}\right) \quad (1)$$

Where R_M and R_m are the maximum and the minimum of solar cycles, S_{om} is the count of spotless events (days) along an interval of two years around the preceding minimum and S_{omn} is the count around the minimum of the incoming solar cycle under test.

Fig. 3 illustrates the above relation (Eq. (1)).

Since cycle 24 is already started, the observed time series of the spotless event at minimum of cycle 24 were used to forecast the amplitude and the time of rise.

The evaluation of the peak of cycle 24 can be given by Eq. (2). Note that our calculation starting from cycle 7 up to cycle 23 (cycles 7–9 and 10–23 are classified as good cycles and modern era).

$$R_{24Somnt} = 183.82 - 0.1814\ S_{omn} = 88.4 \quad (2)$$

The corresponding time of rise is represented by:

$$T_{24Somnt} = 2.722 + 0.0036\ S_{omn} = 4.6\ years \quad (3)$$

Fig. 3.1 illustrates the relation between the count of spotless days (S_{om}) and maximum sunspots number (R_M), while Fig. 3.2 illustrates the relation between the count of spotless days (S_{om}) and time of rise (T_r).

We also used the data sets of the even cycle (8–22) to calculate R_{24E} and T_{r24E} as follows:

$$R_{24E} = 180.634 - 0.1954\ S_{omn} = 77.9 \quad (4)$$

And

$$T_{24E} = 2.8335 + 0.0031\ S_{omn} = 4.5\ years \quad (5)$$

3.2. Forecasting the peak of the solar cycle 24 using aa index

The observed data of geomagnetic index aa, are available only from 1868 onward i.e. from cycle 12 (inclusive). Our predictions are dedicated for estimation of the strength and the timing of the minimum (aa_{min}) for both total and even cycles. The regression equations can be written as:

$$R_{24aamint} = 18.0359 + 8.1359\ aa_{min} = 99.4 \quad (6)$$

$$T_{24aamint} = 4.7627 - 0.073\ aa_{min} = 4.0\ years \quad (7)$$

Fig. 3.3 illustrates the relation between the geomagnetic index (aa_{min}) and maximum sunspots number (R_M), while Fig. 3.4 illustrates the relation between the geomagnetic index (aa_{min}) and time of rise (T_r).

3.3. Forecasting the peak of the solar cycle 24 using solar flux F10.7

The solar radio flux emission at wavelength 10.7 cm (F10.7) tends to follow the sunspots number quite closely. Its observation started in 1947, but the current observation were in 1954 which come to coincide with started time of cycle 19, the most strongest cycle in all records of solar activity. The calculation of the maximum phase and the time of rise using the solar flux at the minimum can be illustrated by the following formula: