Ann. Geophys., 28, 1463–1466, 2010
www.ann-geophys.net/28/1463/2010/
doi:10.5194/angeo-28-1463-2010


Annales Geophysicae

# Size of the coming solar cycle 24 based on Ohl's Precursor Method, final estimate

**R. P. Kane**

Instituto Nacional de Pesquisas Espacias, INPE C.P. 515, 12201-970 São Jose dos Campos, SP, Brazil

Received: 5 January 2010 – Revised: 13 July 2010 – Accepted: 14 July 2010 – Published: 16 July 2010

**Abstract.** In Ohl's Precursor Method (Ohl, 1966, 1976), the geomagnetic activity during the declining phase of a sunspot cycle is shown to be well correlated with the size (maximum sunspot number *Rz*(max)) of the next cycle. For solar cycle 24, Kane (2007a) used *aa*(min)=15.5 (12-month running mean), which occurred during March–May of 2006 and made a preliminary estimate *Rz*(max)=124±26 (12-month running mean). However, in the next few months, the *aa* index first increased and then decreased to a new low value of 14.8 in July 2007. With this new low value, the prediction was *Rz*(max)=117±26 (12-month running mean). However, even this proved a false signal. Since then, the aa values have decreased considerably and the last 12-monthly value is 8.7, centered at May 2009. For solar cycle 24, using *aa*(min)=8.7, the latest prediction is, *Rz*(max)=58.0±25.0.

## 1 Introduction

Prediction of the magnitude of the sunspot maximum *Rz*(max) is important for planning satellite launching For cycle 23, NOAA's Space Environment Center (SEC) recruited a scientific panel to assess the likely development of cycle 23 and their report entitled "Solar Cycle 23 Project: Summary and Panel Findings," later published as Joselyn et al. (1997), mentioned (i) a range of 160–200 of *Rz*(max) of cycle 23 as obtained by considering the even/odd behavior and (ii) a range 110–160 of *Rz*(max) by other methods. The panel gave the greatest weight to precursor methods, since they have proved to be the most successful technique for solar activity predictions in the past. The precursor methods invoke a solar dynamo concept, whereby the polar field in the declining phase and at minimum is the seed of future toroidal fields within the Sun that will cause solar activity (e.g., Schatten and Pesnell, 1993). In one of the precursor methods (Ohl's method), geomagnetic *aa* indices at solar minimum are seen to be well correlated with the succeeding *Rz*(max) (Ohl, 1966, 1976; Brown and Williams, 1969; Ohl and Ohl, 1979; Sargent, 1978). Since then, Kane (1978, 1987, 1992, 1997, 1998), Wilson (1988a, b, 1992), and Wilson et al. (1998) have been studying this aspect for the past three decades. For cycle 24, Kane (2007a) evaluated *Rz*(max) as 124±26 using *aa*(min)=15.5 which seemed to be a minimum at that time. However, some workers (notably L. Svalgaard, private communication) were apprehensive that since *aa*(min) usually occurs a few months later than *Rz(*min), and *Rz*(min) had not yet occurred in 2006, the *aa*(min)=15.5 in March 2006 could be a false alarm. A Solar Cycle 24 Prediction Panel composed of international scientists and presided by D. Biesecker, (details given in http://www.sec.noaa.gov/SolarCycle/SC24/index.html), issued on 25 April 2007, a consensus opinion that cycle 24 would commence in March 2008 (±6 months) and two consensus opinions, that the solar maximum would be 140±20 in October 2011 or 90±10 in August 2012. As it happened, the sunspot minimum was nowhere near the range March 2008 (±6 months) mentioned by them, and the old cycle 23 seems to have ended and the new cycle 24 commenced only in the end of 2009. The sunspot numbers seem to have gone through a minimum of zero in August 2009. In this note, the situation of *Rz*(max) vis-a-vis *aa*(min) is reexamined to see whether a final estimate can be given for *Rz(*max) of cycle 24.

*Correspondence to:* R. P. Kane
(kane@dge.inpe.br)

Published by Copernicus Publications on behalf of the European Geosciences Union.

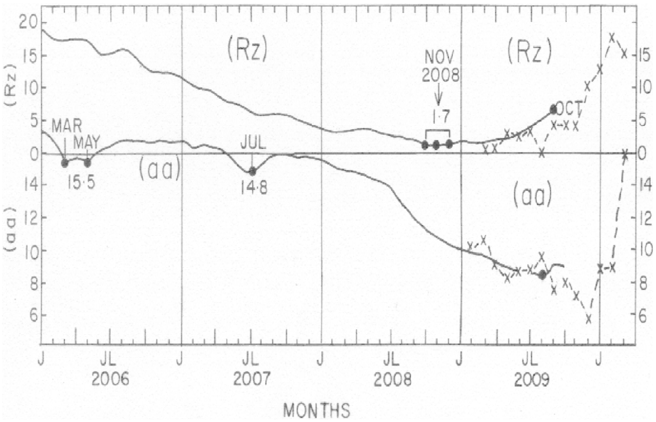


**Fig. 1.** Plot of the 12-month running means of sunspot number *Rz* and geomagnetic index *aa* for January 2006 onwards. Vertical lines mark the month January. Minima are shown by big dots and the corresponding months are indicated.

## 2 Data

The data used are the geomagnetic *aa* indices (the antipodal amplitudes deduced from the K index of Greenwich, England, and Melbourne, Australia; Mayaud, 1973) available at NOAA ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/RELATED_INDICES/AA_INDEX/ and international sunspot numbers *Rz* (McKinnon, 1987, and further data from NOAA websites ftp and ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_NUMBERS). For *aa* indices, data are available from 1868 onward only (cycle 11). However, for 1844–1880, Nevanlinna and Kataja (1993) generated an "equivalent" *aa* index based on the declination data from Helsinki and, for the overlapping period of 13 years 1868–1880, they found a very high correlation (0.99). Hence, we have now *aa* index data for cycle 9 and 10 also (annual values) and for cycle 11 onward (monthly values).

## 3 Present situation

The origin and development of sunspot numbers are described recently in Clette et al. (2007) and Vaquero (2007). The monthly values of *Rz* and *aa* indices vary erratically from month to month. Hence, 12-month running means were evaluated and used. (This is simple average of 12 consecutive monthly values. The centering is half-a-month displaced. To get the centering correct, some workers use 13 consecutive monthly values, with half weight for the first and last values. However, the difference between the two estimates is negligibly small). As shown in Kane (2007a), for cycles 12–23, the *Rz*(min) occurred earlier than *aa*(min) by 3, 5, −2, 2, 14, 8, 16, 12, 7, 7, 4, 16, 9 months. Thus, except for cycle 14 where *Rz*(max) occurred later by 2 months (−2 italicized), the *aa*(min) have occurred with delays ranging from 2 to 16 months. Figure 1 shows the plots of the 12-month running means of *Rz* and *aa* indices for January 2006 onwards. The following may be noted:

1. The 12-month running mean *Rz*(min) seems to have occurred only recently. The mean 1.7 occurred in three successive months October, November, December 2008, followed by values 1.9, 1.9, 2.2, 2.3, 2.3, 3.1, 4.1, 5.5, 6.7 till September 2009. Further, the actual monthly values for July 2009–March indicate that the sunspot activity has started rising. For January–March 2010, monthly values were 13.1, 18.6, 15.4

2. The 12-month running mean *aa*(min) seemed to have occurred first centered at March 2006 and May 2006 with a value 15.5. In Kane (2007a), this value was used in the regression equation $Rz(\max)=(-24.9\pm18.1)+(9.6\pm0.1.2)aa(\min)$ and yielded the preliminary estimate prediction $Rz(\max)=124\pm26$.

3. However, in retrospect, this seems to have been a false alarm. The *aa* values increased in the next few months but decreased later considerably, and attained a second minimum centered at July 2007, *aa*(min)=14.8, smaller in magnitude than the first minimum and 15 months later. This also has proved a false signal and after rising for the next six months, the aa values have decreased considerably. The last 12-monthly running mean for aa index is 8.7, centered on June 2009. If this value 8.7 is used as aa(min), the prediction becomes $Rz(\max)=58.0\pm25.0$.

## 4 Conclusion and discussion

In Ohl's Precursor Method, the geomagnetic activity during the declining phase of a sunspot cycle is shown to be well correlated with the size (maximum sunspot number *Rz*(max) of the next cycle. Kane (1997, 1998, and references therein) and Wilson, Hathaway and Reichmann (1998 and references therein) have been using the *aa* index during the sunspot minimum year as representative of the geomagnetic activity. For solar cycle 24, using *aa*(min)=8.7, the latest prediction is $Rz(\max)=58.0\pm25.0$.

Recently, Du et al. (2008, 2009) examined the Ohl method more critically, and pointed out that a higher correlation does not necessarily mean a successful prediction, In their analyses, a higher correlation often yielded a failure prediction. Therefore, they suggest that when a prediction is obtained, its rationality should be analyzed. As one test, they suggest that the prediction could be considered reliable if the prediction lies very near the regression line and the correlation increases. We tried this criterion. For cycles 9–23, the correlation was +0.918. When the value 8.7 for *aa*(min) in May 2009 was used with predicted *Rz*(max) as 58, the correlation was slightly higher (+0.931). Thus the predicted value

*Rz*(max)=58±25 for cycle 24 should be fairly reliable, and it is in the low *Rz*(max) category.

For cycle 24, there are predictions in a very wide range (see list and references in Kane, 2007a), namely, (a) <70 (three predictions), (b) 70–90 (eight predictions), (c) 90–110 (eight predictions), (d) 110–130 (ten predictions), (e) 130–150 (seven predictions), (f) 150–170 (three predictions), and (g) >170 (four predictions). Our latest prediction of *Rz*(max)=58±25 is in the (a) range of <70, much lower than the average of all predictions (∼115). Thus, if our prediction comes true, predictions in the high range (g) like *Rz*(max) 150–180 (Dikpati et al., 2006), *Rz*(max)=180 (Tsirulnik et al., 1997), *Rz*(max)=185 (Horstman, 2005) would prove grossly erroneous, while predictions in the very low range (a) *Rz*(max)=42±34 (Clilverd et al., 2006) and *Rz*(max)<50 (Badalyan et al., 2001) would prove to be true.

Incidentally, the present author published predictions for cycle 24 by using other methods also and got the results as (i) Kane (2007b) based on solar activity at different solar latitudes, *Rz*(max)=130, (ii) Kane (2007c) based on extrapolation of spectral components, *Rz*(max)=92, (iii) Kane (2008a) based on solar cycle lengths, *Rz*(max)=94, and (iv) Kane (2008b) based on the Ohl-Kopecky rule and the three-cycle periodicity scheme, *Rz*(max)=106. Almost all these (except 130 in Kane, 2007b) are below the statistical average of ∼115 for the 23 cycles. Thus, cycle 24 is likely to be below average. Recently, a review on this solar minimum has been published by Russell et al. (2010).

*Acknowledgements.* This work was partially supported by FNDCT, Brazil, under Contract No. FINEP-537/CT.

Topical Editor R. Forsyth thanks Z. Du and J. Vaquero for their help in evaluating this paper.

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