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Preliminary forecast for the peak of solar activity cycle 24

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Abstract

Our forecast for the development phase of solar cycle 23 came out to be true; one of the very few to have attained this status out of several forecasts made. We review the details of the forecast and how it fared as the events unfolded in time. We note the present status of IMF intensity B and the planetary index Ap. We draw inferences as to what to expect for the development phase of cycle 24; several forecasts have already been made, they cover all possible scenarios, ranging from a very active to the quietest cycle in a century. Our preliminary forecast for the smoothed sunspot number at cycle 24 maximum is 101 ± 5, indicating that cycle 24 will be about 20% less active than cycle 23; the possibility that next three solar cycles may be progressively less active cannot be ruled out.

Keywords: Sunspot number; Cycle 24; Forecast

1. Introduction

A forecast for the parameters of a solar activity cycle maximum is the first step in predicting the space climate to unfold. A posting on the Belgian Solar Influences Data Analysis Center (SIDC) states that first sunspot of cycle 24 appeared on 4 January 2008. We believe cycle 23 reached minimum several months later; monthly mean sunspot numbers (SSNs) for July and August are low and the 2008 annual mean SSN is 2.8. Although some new ideas have been advanced as to how the solar dynamo works, the physical foundations for theoretically making any precise forecast remain shaky. So, there is room for an empirical data driven approach to the problem.

A NOAA panel of 12 international experts is split down the middle; half of them predict a moderately strong cycle of 140 ± 20 sunspots at the maximum of the cycle in October of 2011, the other half predict a moderately weak cycle of 90 ± 10 sunspots peaking in August of 2012 [News from NOAA dated 25 April 2007]. Even so, several early forecasts have been made already (Pesnell, 2008).

Hathaway and Wilson (2006) choose the peak in geomagnetic activity index (aa) before solar cycle 23 minimum as a precursor indicator. They assert, "...the solar activity cycle 24 will be much higher than average...with a peak sunspot number of 160 ± 25." Dikpati et al. (2006) claim to have a prediction tool from the calibrated flux transport dynamo model developed by them. They state, "...the cycle 24 will have a 30–50% higher peak than cycle 23...."

In contrast to the extreme numbers quoted above, Svalgaard et al. (2005) use a method pioneered by Schatten et al. (1978) based on the solar polar magnetic field as a precursor indicator, claiming their method is rooted in solid physics. They infer, "....the solar cycle 24 (~2011 maximum) will have a peak smoothed monthly sunspot number of 75 ± 8, making it potentially the smallest cycle in the last 100 years." Schatten (2005) notes, "...the coronal features do not show the characteristics of well-formed polar coronal holes associated with typical solar minima but rather resemble stunted polar field levels...," inferring a smoothed sunspot number at maximum of 80 ± 30, heralding a 'Fair' space weather for cycle 24. We note that high helio-latitude magnetic fields are difficult to measure.

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2. Heuristic approach

We rely on a heuristic approach using the planetary index Ap devised by Bartels (1962); these data have been archived since 1932. The index is computed from data obtained at 12 mid-latitude magnetic observatories. For larger coverage, we use the aa index devised by Mayaud (1972) from two nearly antipodal magnetic observatories in England and Australia. The data go back to 1868, they have been extended back in time for two additional solar cycles (1843 onwards) by Nevanlinna and Katja (1993) using magnetic declination data at Helsinki, Finland; the quality of these data obtained at just one site (compared to Mayaud data) may be questionable, they are included here only for long term baseline reference purposes. The indices Ap and aa have linear scales and are highly correlated. Ahluwalia (1998, and references therein) showed that there exists a 3-cycle quasi-periodicity in Ap data (for every third cycle Ap value is lowest); it also shows up in galactic cosmic ray intensity variations (Ahluwalia, 1997) and in the frequency of occurrence of auroras for a period of about five centuries (Silverman, 1992). Its cause is unknown at present. Ahluwalia (1998, 1999a, 2000a) noted that the annual mean value of Ap, one year into the onset of a new cycle, predicts the amplitude of the new cycle (monthly mean of smoothed SSN at cycle maximum *minus* the monthly mean smoothed SSN at solar minimum) with an uncanny precision. He inferred the monthly mean smoothed SSN at cycle 23 maximum to be $131.5 + 33/-20$, where the $\pm$ represent extreme deviations between the expected and the predicted values for cycles 19 and 21 (Ahluwalia, 2000a), they are not the usual errors. Wilson and Hathaway (1999) questioned this number, characterizing it as being overly on the low side and unlikely to be correct. Ahluwalia (1999b) defended the forecast against their criticism; it is gratifying that the observed number is 120.8, very close to the forecast. In the meantime, we devised a scheme to forecast the cycle rise time to maximum (Ahluwalia, 2003), plotting annual mean aa index at the minimum (aamin) of SSN cycle against the rise time of the cycle (number of months between smoothed sunspot numbers at cycle minimum and maximum) beginning with cycle 9 minimum (1855). The correlation is linear and predicts cycle 23 rise time of 43 ± 6 months, the observed number is 47 months (April 2000). The Ahluwalia forecast for cycle 23 is fairly accurate.

We note that the data of sum Kp (logarithmic scale) have been used for successful forecasts for cycles 20 by Ohl (1966) and 21 by Ohl (1976), using a different approach; for other forecasting methods, the reader may refer to the list by Brown (1992) for 31 predictions for cycle 22 and the list by Kane (2001) for 20 predictions for cycle 23.

3. Data analysis

Fig. 1 shows a plot of the annual mean value of the SSNs and the aa index for 1843–2007 (solar cycles 9–23). We draw attention to the following features.

- The dashed lines in the diagram highlight a 3-cycle quasi-periodicity in aa index; no such trend is present in the timeline of SSN *minima*. We note that Ap minimum in 1980 (right near the maximum for cycle 21) is lower than cycle 20 minimum in 1976. Ahluwalia (2000b) provides one plausible explanation for this anomaly.
- We note that the aa index seems to follow a positive slope after 1901 and the slope of the line is negative prior to 1901. Also, the data point for 2007 has a lower value compared to the datum point 10 years earlier (1997). This raises a question whether the trend in 3-cycle quasi-periodicity is set to turn negative in future. If the answer is yes, several important consequences follow. We discuss some later.
- We note that the four most active cycles (18, 19, 21, and 22), in the last 400 years, all occurred in the later half of 20th century. One wonders if this has a bearing on future cycles in 21st century. No answer is available yet.

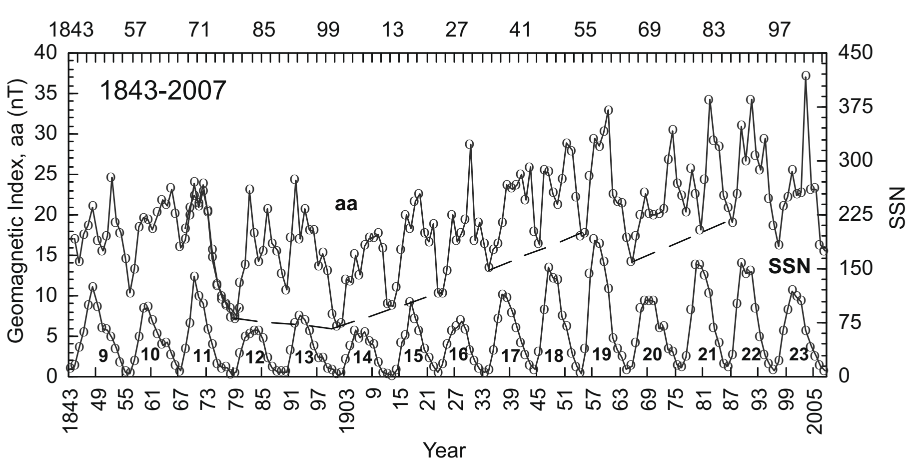

Fig. 1. Annual mean values of SSNs and aa index are plotted for 1843–2007, 3-cycle quasi-periodicity is indicated by the dashed lines. See text for more details.