Some comments on D. H. Hathaway & R. M. Wilson's preprint

Geomagnetic activity indicates large amplitude for sunspot cycle 24

http://solarscience.msfc.nasa.gov/papers/hathadh/HathawayWilson2006-preprint.pdf

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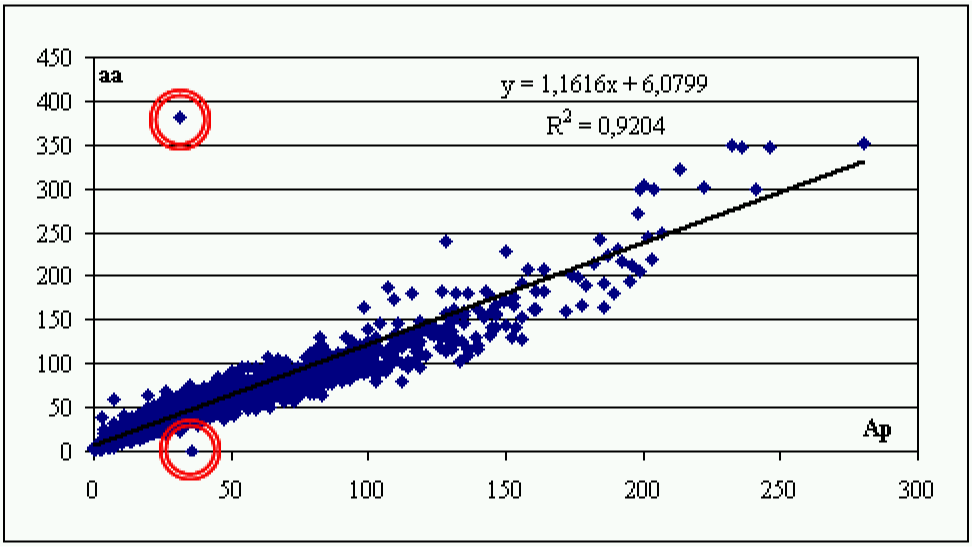
Abstract

The preprint makes a prediction for the amplitude of the upcoming solar cycle based on a geomagnetic activity maximum that occurred in October 2003. This is the time during which the famous Halloween groups were boosting solar activity. In the comments underneath, it is shown that a simple correction for this sunspot activity brings down the SC24 amplitude by 7%. More importantly, the initial smoothing performed in the preprint leaves out valuable signals in the data-series possibly masking a much lower amplitude for the next cycle.

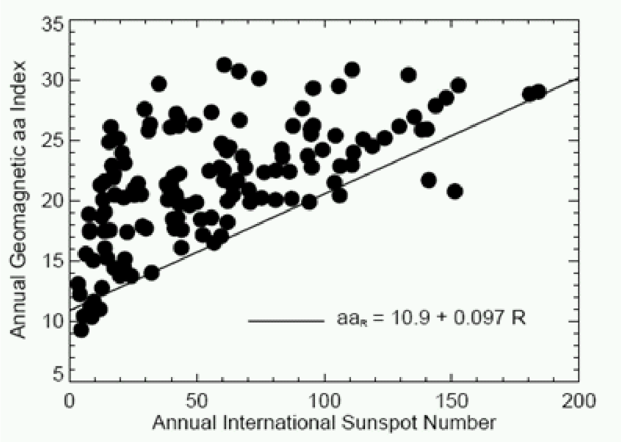
Recreating the results of the preprint

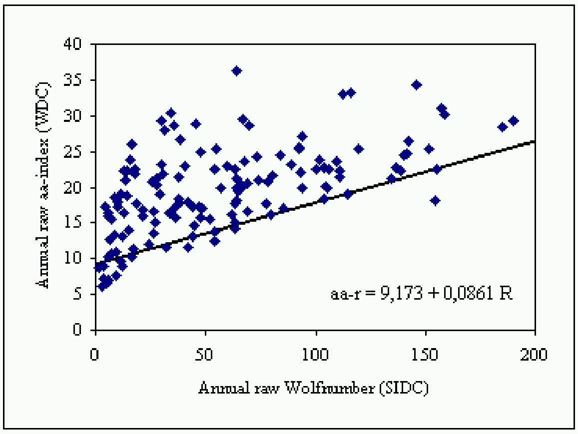
In a first step, an attempt was made to recreate the results of the preprint. The daily aa-data were taken from the World Data Center for Solar-Terrestrial Physics, Moscow at http://www.wdcb.rssi.ru/stp/data/geomagni.ind/aa/aa/aaindex . The increase of 3 nT on aa-values prior to 1957 was not applied. Also no smoothing to minimize short-term variations was applied. It is the author's opinion that smoothing data before actually calculating with them, may leave out valuable information contained within the series.

A few corrections were made. Data-blancs for the years 1988 and 1989 were removed, and the correct month for 26 October was introduced ("10" in stead of "19"). More importantly, a recalculation of the daily aa-index was performed for 31 Dec 1999 and 11 May 2003 based on comparison with the Ap-index (http://www.wdcb.ru/stp/data/geomagni.ind/kp_ap/kp-ap.plt). For the time-frame January 1932 – November 2004, a linear relationship between Ap and aa was calculated. Assuming the implicite correctness of the Ap-index, the original aa-values of respectively -1 and 381,3 were changed to 48 and 42.



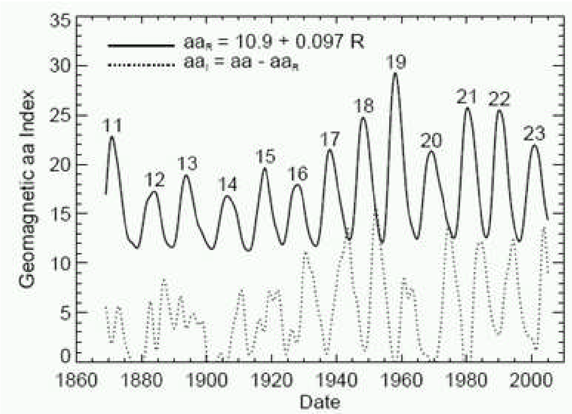
Following the authors' method, a binning was then applied on the *yearly* aa- and R-values. In this approach, it was chosen to rank the yearly Wolfnumbers in increasing order and determine for each bin of 7 pairs (R, aa) the minimum aa-value. Then, a least-squares fit was calculated through these 20 pairs (minimum aa and corresponding R). This lead to a similar relationship (r = 0,86) than the one obtained by the authors. Differences are probably due to the not-smoothing of initial data and possibly also to a difference in binning method.

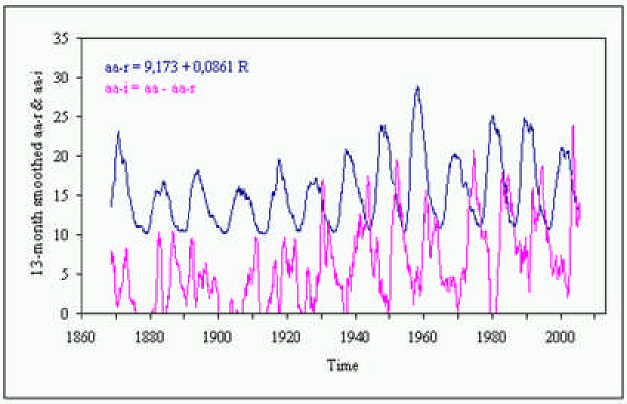




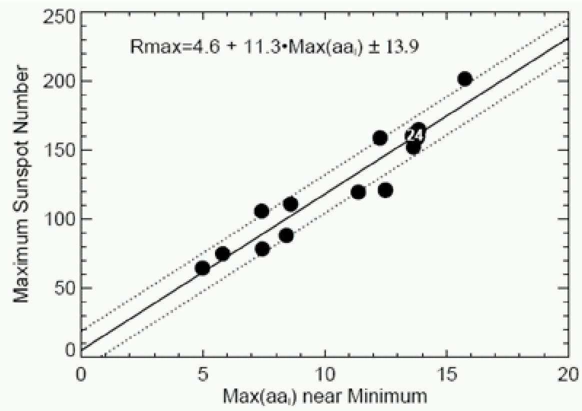
One could opt to bin the *monthly* aa- and R-values. Though this leads to a different relation (aa-r = 4,988 + 0,0591 R, with correlation r = 0,95), the final results and conclusions are similar. Thus, it was chosen to follow the authors' methodology.

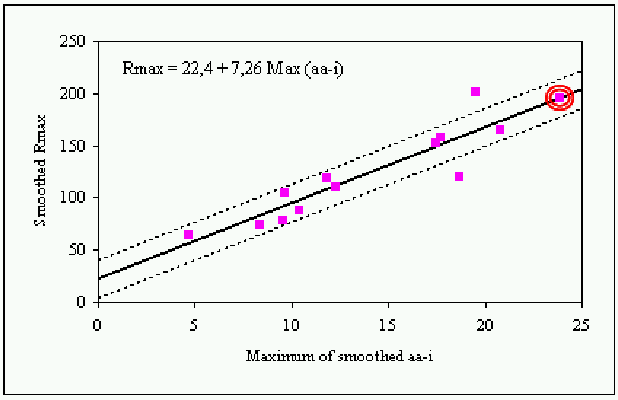
From the relationship between aa-r and R, the interplanetary index aa-i was calculated. Both the aa-i and aa-r were then smoothed using the most common smoothing formula, i.e. a 13 month running average with half-weight for the first and last value. The authors' graph and the reproduced one have similarities, but also some differences. The overall shape and evolution of the curves is there. Also, the calculated aa-i occasionally becomes negative (?!). Major differences are that the aa-i curve clearly shows more detail (more extrema), and that the maximum aa-i prior to SC 21 and 24 are higher than that prior to SC 19. In general, the maxima of aa-i are about 3 higher than those calculated by the authors, which is due to the different relationship between aa-r and R, and the difference in smoothing of the data. The same explanation holds true for the difference in timing of the maxima.





From the aa-i curve, a relationship was calculated between the last aa-i maximum prior to the aa-r minimum, and the maximum smoothed Wolfnumber of the subsequent solar cycle. Care was taken that always the last clear maximum was used whenever there were multiple aa-i maxima in the descending phase of the previous sunspot cycle. The correlation between the two quantities (r = 0,90) is slightly less than that obtained by the authors (r = 0,94), but still very good. The standard deviation in the amplitude prediction is only 18,2, but it is clear this deviation can increase to twice this sigma for some cycles (SC 19 and 23).





As aa-i reaches a maximum in August 2003 of 23,86, a maximum smoothed Wolfnumber for SC24 of 195,6 +/- 34,0 (90% prediction interval) can be predicted. This is even higher than that made by the authors, i.e. 160 +/- 25, and would indeed herald another powerful solar cycle similar to SC19, 21 and 22.

Correcting for the sunspot induced severe geomagnetic disturbances

It is believed that the authors' prediction for SC24 is heavily influenced by the activity of the Halloween groups in October-November 2003. Therefore, it was decided to make corrections for all the high daily aa-values by making distinction in the causes that produced such powerful geomagnetic storms. The reasoning is that if a sunspot-caused aa-index of 350 is brought back to a more normal value of 50, then the aa-index for that month drops immediately by (350-50)/30 = 10 units! This means a (absolute) decrease by 33% for months with high geomagnetic activity (aa of about 30), which should have an effect on aa-r, aa-i, thus also maximum aa-i and therefore also on the predicted amplitude of the subsequent solar cycle.

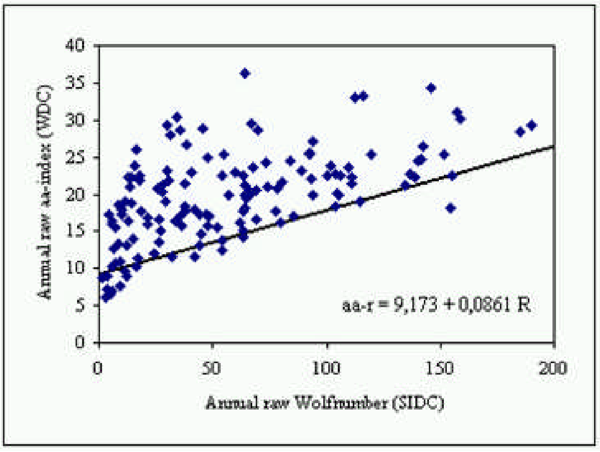
For the 50435 aa-values, it became clear that only on 581 days (1,2%) an aa-index occurred equal to or bigger than 80. 279 of these were found to be equal to or higher than 100. For every of the 581 indices, the source of the disturbance was verified. This was quite easy for the years 2001 to 2006, as any significant disturbance (and its cause) is reported on NASA's Spaceweather website (http://www.spaceweather.com/). If sunspots were involved, then the average aa of the day prior and the day after the disturbance was taken. Note this is a very conservative approach, as a disturbance usually already starts before the day in question , and geomagnetic effects usually linger for some time too. If no sunspots were involved, no correction was made to the daily aa-index.
Between 1976 and 2001, GOES X-ray flare data (ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_FLARES/XRAY_FLARES/) were used, in combination with MSFC sunspot data (http://solarscience.msfc.nasa.gov/greenwch.shtml). If in the 2 to 3 days prior to the disturbance no highenergetic flare had occurred, it was assumed the geomagnetic disturbance was not sunspot related.
Between 1950 and 1976, drawings from the Kanzelhöhe Observatory (http://cesar.kso.ac.at/synoptic/draw_years.php) were used in combination with MSFC sunspot data. If in the 2 to 3 days prior to the disturbance no complex sunspot group was in

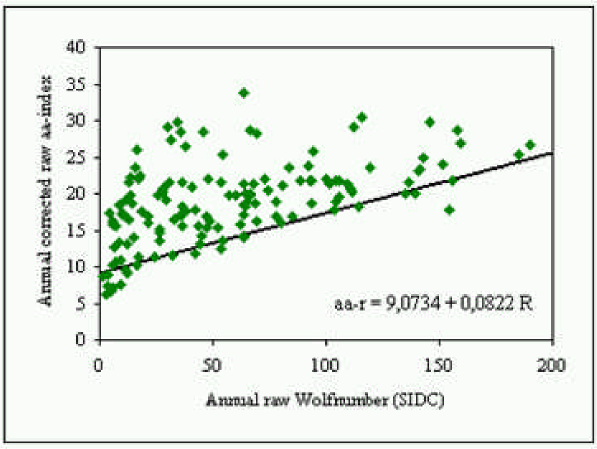
the inner half of the sunspot disk, it was again assumed that the geomagnetic disturbance was not sunspot related.
For the years 1874 to 1950, the same reasoning was followed, but now only based on the MSFC sunspot data. The area, position and magnetic configuration of the sunspotgroup were taken into consideration.
Prior to 1874, daily SIDC sunspot data (http://sidc.oma.be/sunspot-data/) were used. High Wolfnumbers 2 to 3 days prior to the geomagnetic disturbance were considered as a high likelihood the disturbance was caused by sunspots.
If several sunspot groups were likely to have caused the geomagnetic activity, then the aa-index was adapted. If there was no certainty whether a sunspot group, a coronal hole, or even a filament eruption had caused the geomagnetic disturbance, then the aa-index was not corrected.
In 75% of the cases examined, a correction was performed. This resulted in an average decrease of 87 per corrected event. It is noteworthy that two thirds of the events, as well as two thirds of the corrections, occurred after 1944, i.e. there was some reasonable good documentation (Kanzelhöhe drawings, GOES X-ray flares, Spaceweather) available to make the decision.

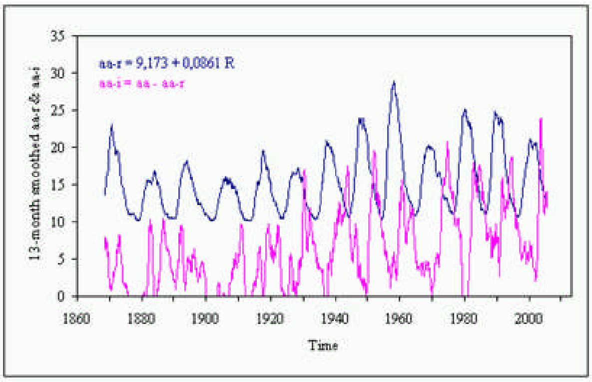
SC	Period	Uncorr.	Corr.	Avg/Event
11	1867-1878	6	29	-89,8
12	1878-1890	4	16	-117,3
13	1890-1901	12	18	-103,1
14	1901-1913	1	17	-98,8
15	1913-1923	3	21	-84,9
16	1923-1933	11	14	-91,3
17	1933-1944	12	35	-105,9
18	1944-1954	20	41	-83,1
19	1954-1964	16	68	-84,6
20	1964-1976	15	36	-75,6
21	1976-1986	17	46	-75,7
22	1986-1996	13	49	-76,5
23	1996-2005	12	49	-87,8
		142	***439***	***-87***
		24,4%	***75,6%***	***+/-12,3***

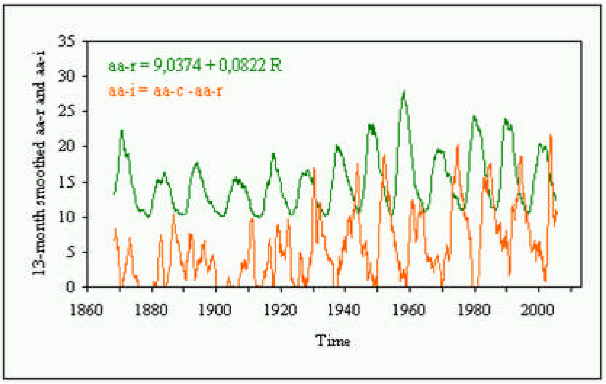
Recalculating aa-i and SC24-amplitude using the corrected aa-index
With these corrections on the daily aa-indices, the entire procedure as discussed in part one was repeated. First of all, the relation between R and aa-r was determined. The relation is quite the same with a similar correlation (r = 0,86).

From the corrected aa-index and aa-r, the aa-i was calculated and put into a graph. As can be seen, there are only minor differences with the previously calculated aa-i graph. The accompanying table shows that the main differences are in the prediction for SC12 and 24. These come down significantly, but not enough to really alter the overall conclusions made by the authors.





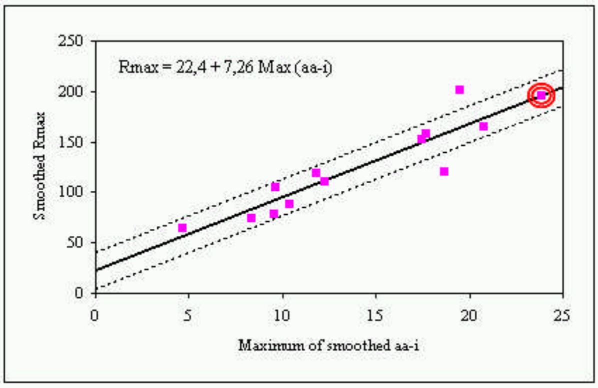


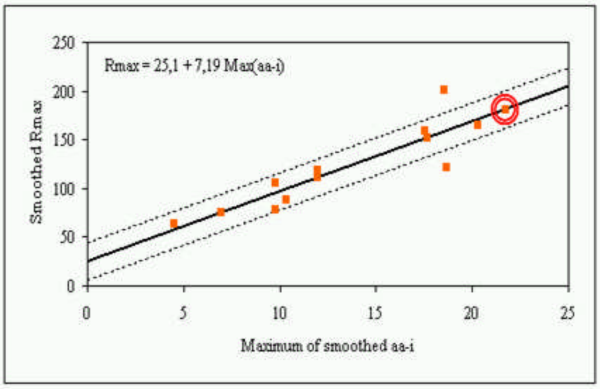


Prediction	Original		Corrected		Change aa-i	
SC	Timing	aa-i	Timing	aa-i	delta	%
12	1873,03	8,33	1873,28	6,98	-1,35	-16,2
13	1886,61	10,41	1886,78	10,36	-0,05	-0,5
14	1898,7	4,68	1898,86	4,54	-0,14	-3,0
15	1910,78	9,63	1910,78	9,8	0,17	1,8
16	1922,28	9,6	1922,28	9,77	0,17	1,8
17	1932,2	11,8	1932,2	11,97	0,17	1,4
18	1943,78	17,48	1943,78	17,64	0,16	0,9
19	1952,03	19,5	1952,2	18,55	-0,95	-4,9
20	1963,2	12,28	1963,2	11,97	-0,31	-2,5
21	1974,7	20,78	1974,7	20,33	-0,45	-2,2
22	1984,78	17,68	1984,78	17,54	-0,14	-0,8
23	1994,61	18,68	1994,61	18,66	-0,02	-0,1
24	2003,61	23,86	2003,61	21,73	-2,13	-8,9

From the aa-i curve, a relationship was again calculated between the last aa-i maximum prior to the aa-r minimum, and the maximum smoothed Wolfnumber of the subsequent solar cycle. Care was taken that always the last clear maximum was taken whenever there were multiple aa-i maxima in the descending phase of the previous sunspot cycle. The correlation between the two quantities (r = 0,89) is slightly less than that obtained previously (r = 0,90), but still very good. The standard deviation in the amplitude prediction is only 19,2, but it is clear this deviation can increase to twice this sigma for some cycles (SC 19 and 23).
As aa-i reaches a maximum in August 2003 of 21,73, a maximum smoothed Wolfnumber for SC24 of 181,2 +/- 35,8 (90% prediction interval) can be predicted. This is still higher than that made by the authors, i.e. 160 +/- 25, but over 7% lower than the original prediction in this article. There is no doubt that a detailed examination of the various geomagnetic disturbances

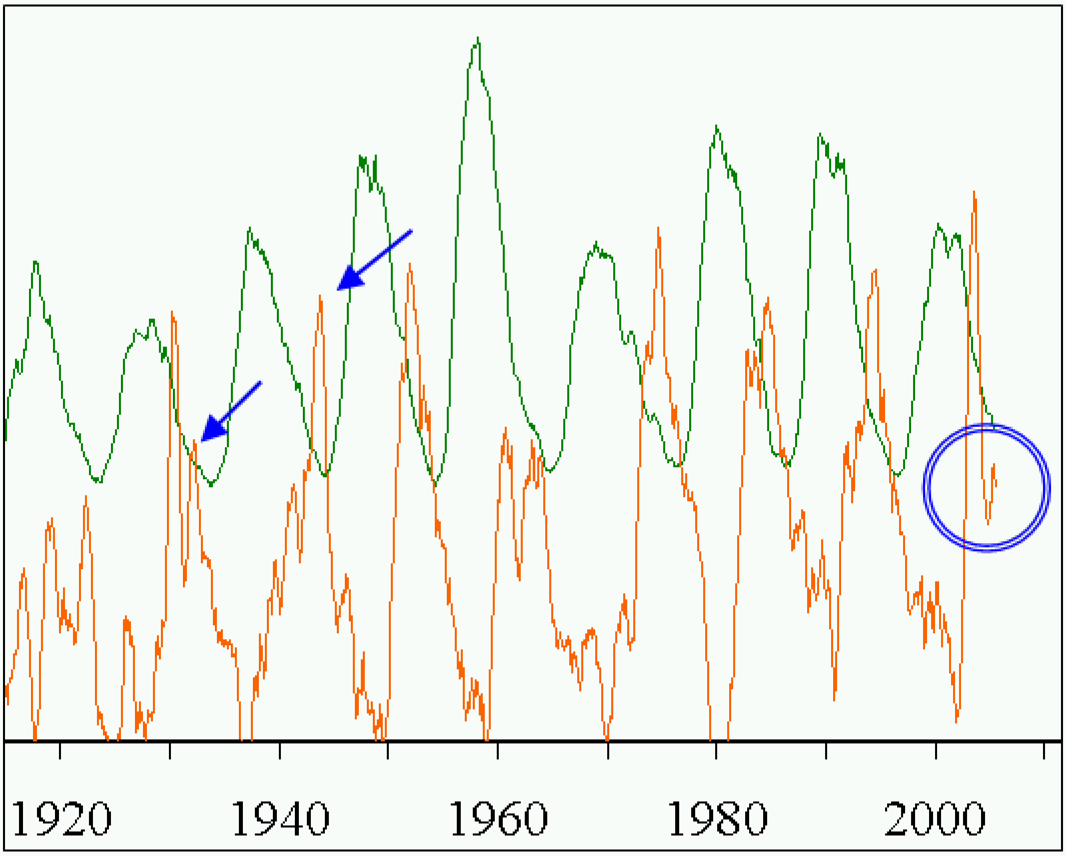
would lead to a much more refined aa-i, and thus to a better SC24 prediction. This effort is of course limited by the available data.





A second peak in aa-i during the declining phase of SC23?

Examining the aa-i graph that was calculated from the corrected aa-i indices, it became clear that a second peak is visible in the declining branch of SC23. The occurrence of a second peak is a very common and important feature, as can be seen in the prediction of the SC 17 and 18: Ignoring this second peak would lead to some contradictory predictions!

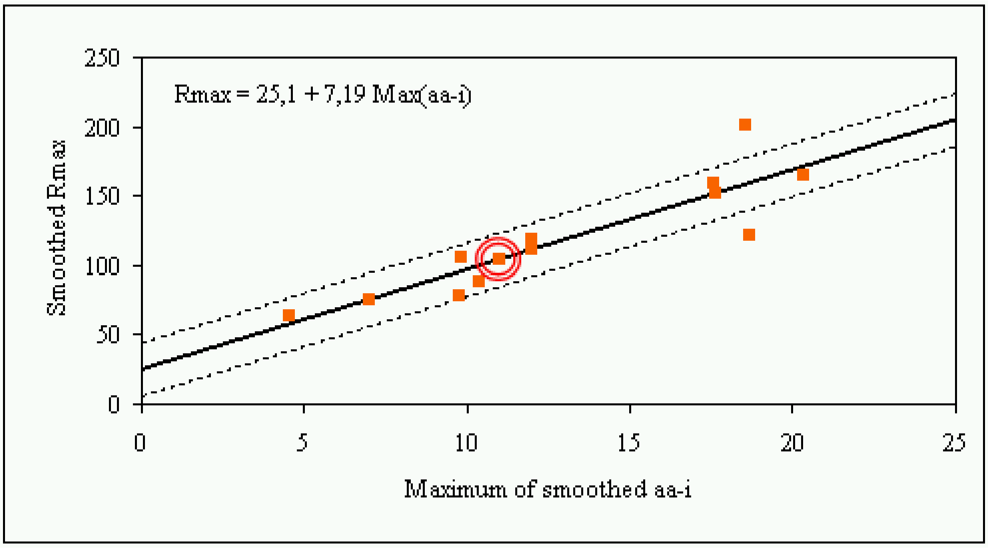


It is to be emphasized that this peak is not some kind of temporization, but a genuine increase and decrease in the evolution of aa-i, often occurring about 2 years after the first maximum aa-i. Not all cycles exhibit this second peak: when the aa-i is followed by a very low or very active solar cycle, no such second peak can be clearly distinguished. This may be due to the aa-i diffusing in the activity of the ongoing solar cycle, or that the peaks are too closely spaced to get distinguished. The second peak in the declining phase of SC23 is right on time, but its (percentual) amplitude is the lowest of the entire series.

Prediction	Max1		Min		Max2		Max1-Min		Min-Max2		Max1-Max2	
SC	Timing	aa-i	Timing	aa-i	Timing	aa-i	delta T	% aa-i	delta T	%aa-i	delta T	%aa-i
14	1896,28	6,55	1897,36	2,14	1898,86	4,54	1,08	-67	1,5	112	2,58	-31
15	1909,28	3,66	1909,61	2,66	1910,78	9,8	0,33	-27	1,17	268	1,5	168
16	1919,28	8,89	1921,28	3,86	1922,28	9,77	2	-57	1	153	3	10
17	1930,28	17,03	1931,36	6,19	1932,2	11,97	1,08	-64	0,84	93	1,92	-30
18	1941,36	10,21	1941,95	7,11	1943,78	17,64	0,59	-30	1,83	148	2,42	73
20	1961,28	11,71	1961,95	6,43	1963,2	11,97	0,67	-45	1,25	86	1,92	2
23	1992,03	10,84	1992,45	9,47	1994,61	18,66	0,42	-13	2,16	97	2,58	72
24	2003,61	21,73	2004,78	8,65	2005,36	10,99	*1,17*	*-60*	*0,58*	*27*	*1,75*	*-49*
Averages for SC14 to SC23							**0,88**	**-43**	**1,39**	**137**	**2,27**	**38**

Based on these statistics, it is very likely that this second May-2005-peak is the indicator for the next cycle's amplitude, and not the August-2003-one discussed in the previous paragraphs. It must be noted too that the 2005-peak is not visible in the analysis by Hathaway and Wilson, because of the applied smoothing method. A 24-month Gaussian FWHM is bound to wipe out all shorter term variations in the data-series, thus eliminating potentially valuable information and leading to erroneous conclusions and predictions.

Applying the found relationship between the corrected aa-i and subsequent cycle amplitude, SC24 should reach a maximum of 104,0 +/-35,8. Note that the timing of occurrence would become much more likely too. In view of the currently ongoing solar activity, a maximum of 104,0 occurring in July 2011 seems much more acceptable than an amplitude of 181,2 in October 2009, though there is a rather large uncertainty of 21 months.



Conclusions

In this article, it has been shown that simple corrections on the aa-index for sunspot induced geomagnetic disturbances can quickly bring down the predicted amplitude. For SC24, this decrease amounts to 7%. More importantly, it is shown that the applied smoothing leaves out valuable information in the aa-i data, and contributes to an excessive amplitude prediction for SC24. Taking these corrections into account, and assuming the methodology and underlying physical processes are correct, a SC24-amplitude of 104,0 +/- 35,8 is predicted for July 2011 +/- 21 months based on the currently available solar data.