Notes on HMF at Minima and Rmax

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Choice of Sunspot Number and Definition of Cycle Size, Rmax

The 'size' of a sunspot cycle is a fuzzy concept. Often there are several peaks. These can be 'obscured' by suitable smoothing. Traditionally a 13-month moving average [with end-points having half-weight] is used. That sometimes still leaves multiple peaks. In this little note, I have opted for an alternative method [although the result must not depend on the exact procedure]. I 'fit' [by eye] a rounded upward convex curve to the yearly values of the sunspot number and estimate the 'size; of the cycle from that. In addition, one could ask *which* sunspot number to use, Group number, Zurich number, American number, etc? I have opted for using my own 'corrected' sunspot numbers. If the main conclusion turns out to depend qualitatively on the choice, it is probably spurious anyway.

The HelioMagnetic Field (HMF) at Solar Minima

To have a homogeneous dataset I use HMF |***B***| derived from IDV [even though spacecraft data is available since 1963]. As a measure of the HMF at minimum I took the average HMF for the suite of three consecutive B-values that were lowest near minimum, as additional data I use the lowest yearly HMF B nearest the minimum [most often right at the minimum]. Figure 1 shows [top – red and pink] these values since cycle 12:

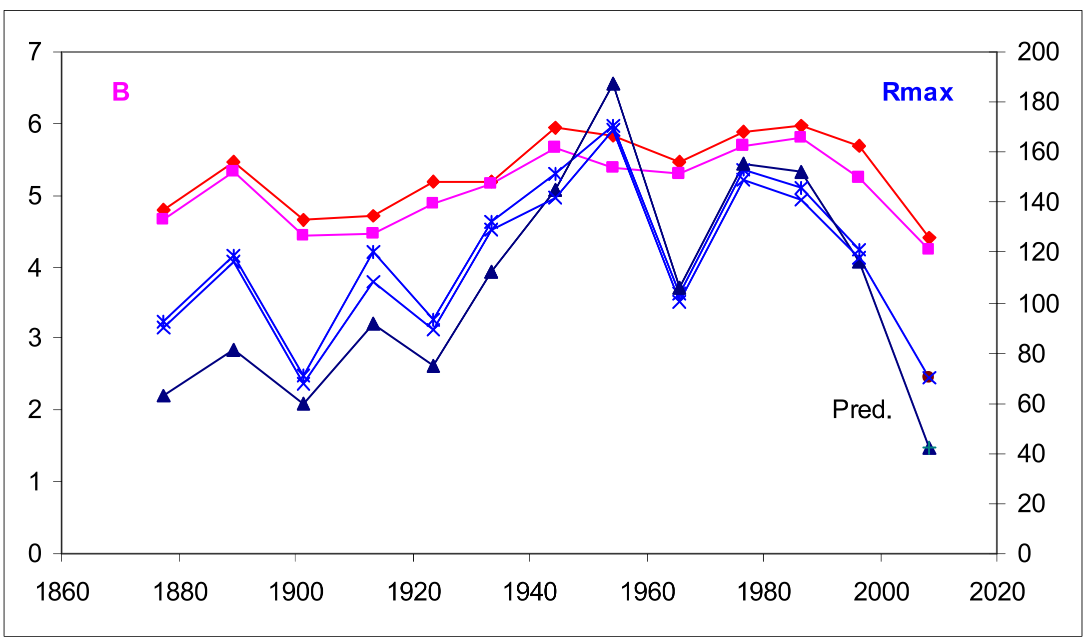

Figure 1

It seems that the precise definition of 'minimum' B does not matter much as the red and pink curves track each other well.

Also shown [light blue curves] is Rmax as defined above for the following cycle, including also the highest value for each cycle. Again it matters not which definition is used. For completeness, the dark blue curve [with triangles] shows the values using the 'official' Rzi yearly values. The values for cycle 24 are predicted as detailed below. The lower prediction using Rzi is due to the larger spread of the values.

Correlation between Bmin and Rmax

It is evident that there is some correlation between Bmin and Rmax. Figure 2 shows that explicitly:

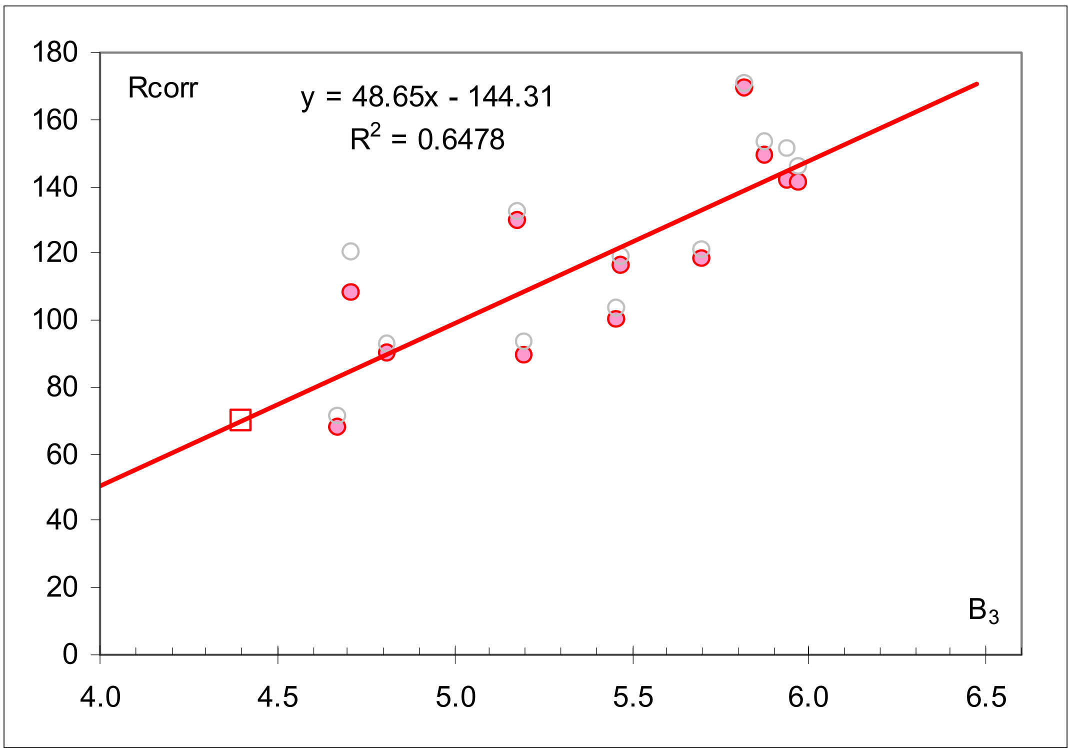

Figure 2

The open gray circles show the result using the highest yearly R-value for each cycle. The open red square is the predicted value [4.4, 70] for cycle 24 using the regression line shown. The correlation coefficient is about the same as in Figure 5 of Wang and Sheeley [2009 – the paper I reviewed].

So, the paradigm that says Bmin = Bfloor + Bcme with the assumption that Bcme is not a predictor is refuted by the correlation, unless the CME-rate is a predictor [which we shall not entertain for the moment]. Before we go on, it is of interest to explore the correlation a bit further.

Total flux Correlation

Dynamo theory indicates that it is the *total* amount of flux generated that should depend on the polar fields, so a more useful measure of the 'size' of a solar cycle may not be Rmax, but the total magnetic flux. The latter we may approximate [under the assumption that the average flux per active region does not have a secular variation – which it may well have] by the sum of the yearly R-values over the cycle.

Plotting the cycle sums using our corrected R-values against Bmin we get Figure 3:

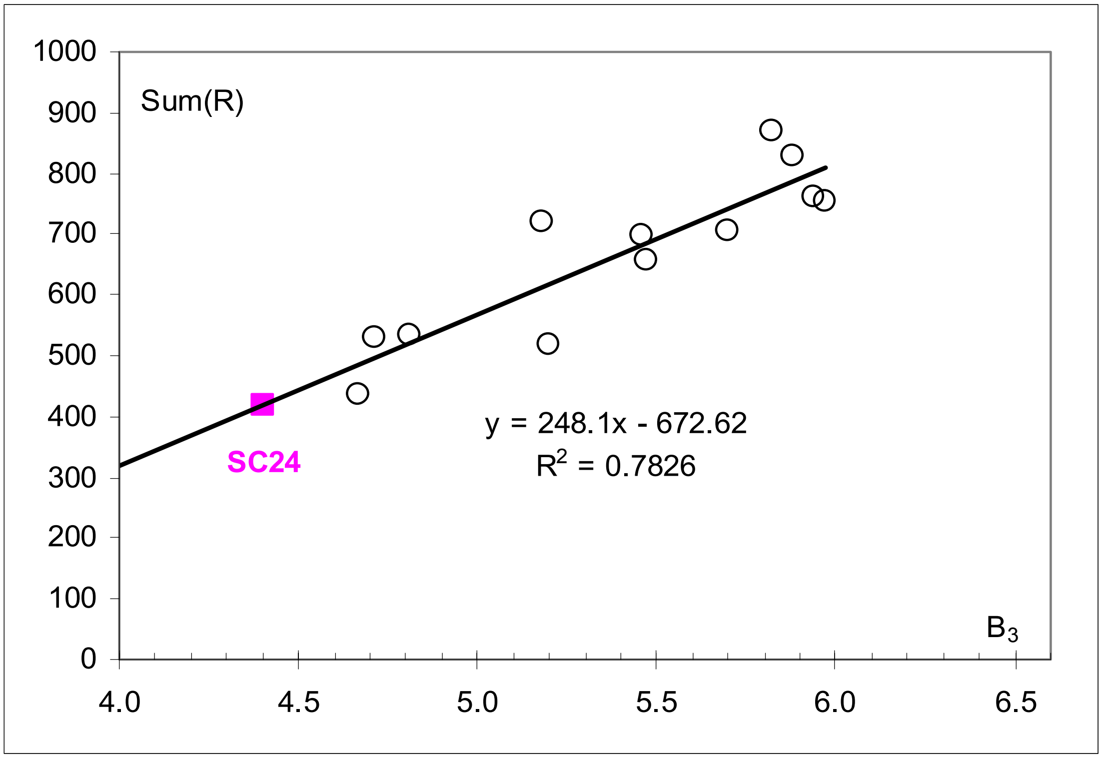

Figure 3

The correlation has now improved markedly. The pink square is the predicted sum for cycle 24. We can convert that into an 'equivalent' Rmax [74] by multiplying by 0.1775 [= average Rmax/average cycle sum]. Here is the time evolution of Sum(R) and Bmin:

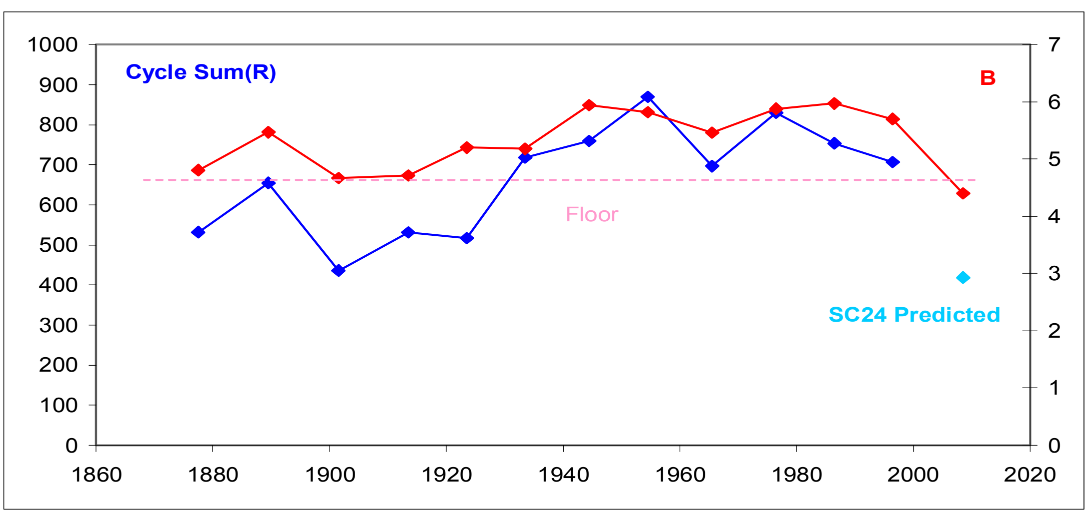

Figure 4

It thus seems that there is a strong correlation between the size [measured by the cycle sum] of the next cycle and Bmin.

We have always said that Bmin is a bit elevated over the Floor because of 'residual' CME activity. One way of quantifying this is to plot Bmin against the average Sunspot Number for the three years:

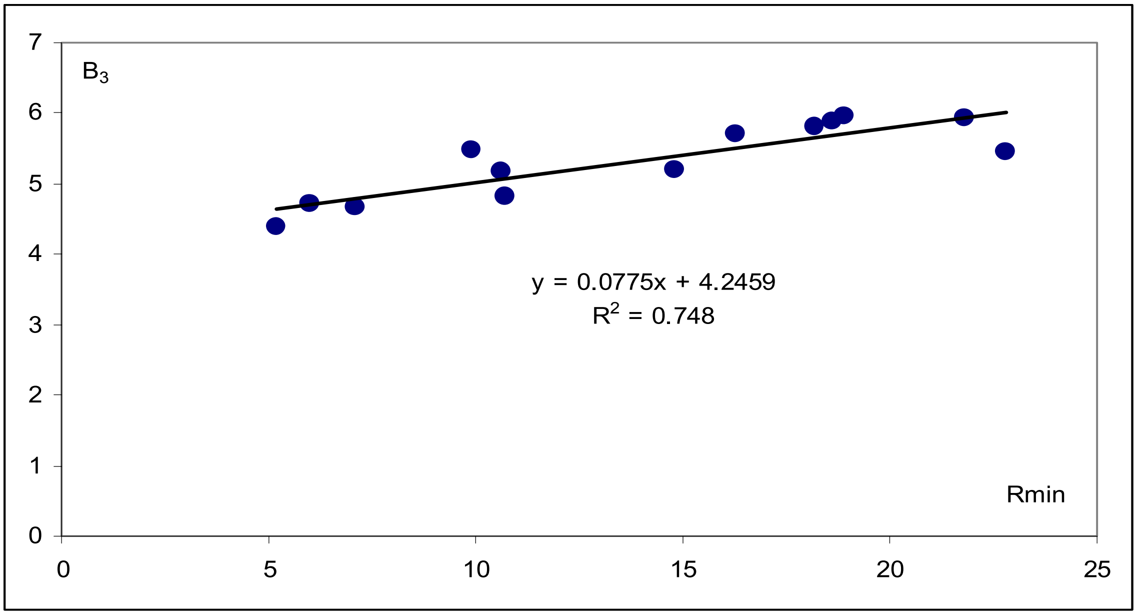

Figure 5

Following our paradigm we can now correct Bmin for the CME-contribution [as a function of Rmin, using the regression slope in Figure 5]. We get:

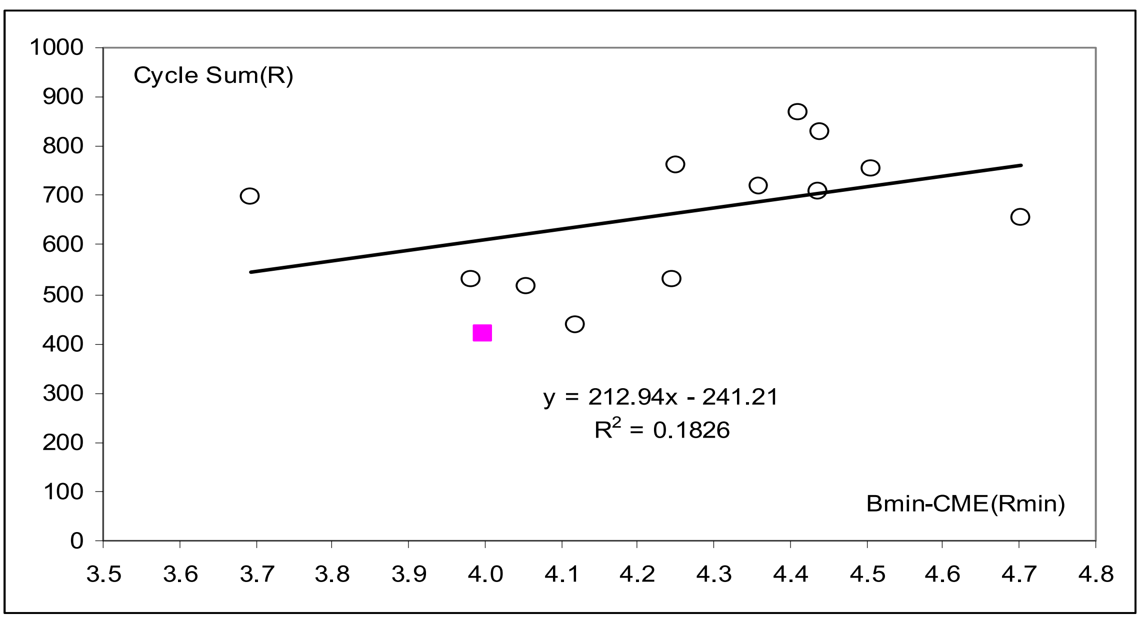

Figure 6

Now there is almost no correlation left.

The conclusion one may draw from this is that the CME rate at minimum [or equivalently Rmin] is a predictor of the next cycle. There is, in fact, a reasonable correlation:

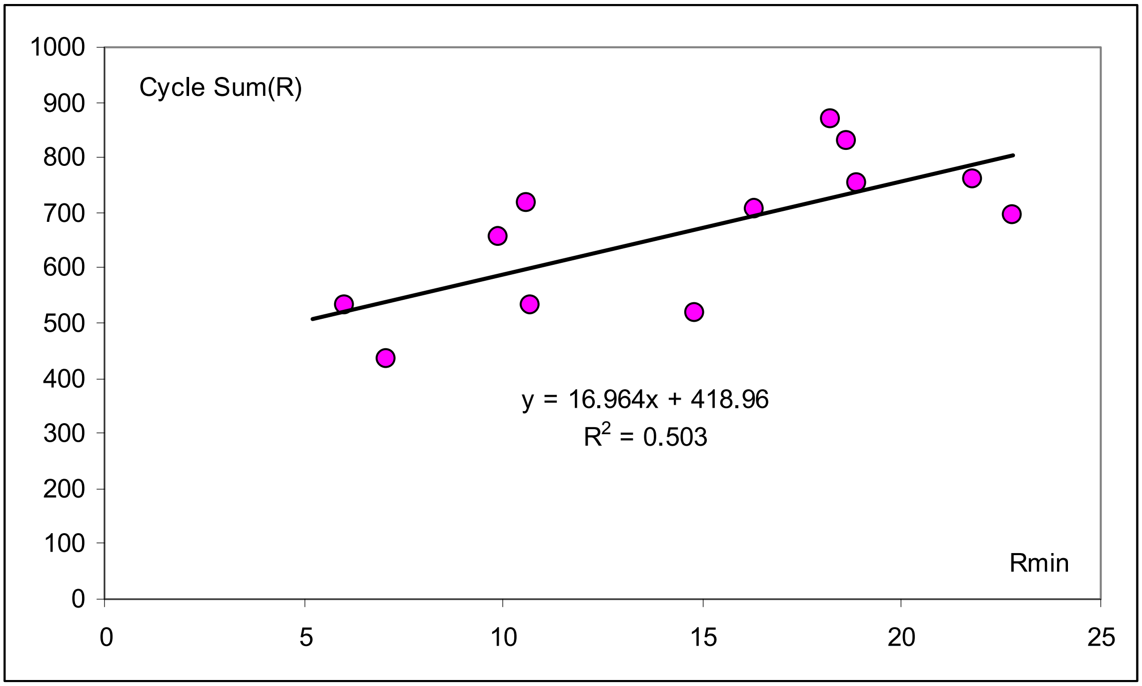

Figure 7

This is not what I would have liked, although other people [e.g. Schlüssler et al.] seem to find similar things [blaming it on ‘overlap’ between the cycles].

The important Figures are Figures 3 and 5. Since [according to Figure 1] the smallest yearly value of B is about 0.25 nT smaller than our ‘Bmin’, the true floor comes out to be 4.0 nT. Figure 5 nicely explains the apparent variation of the ‘floor’.

The polar fields have not entered into this at all. This is consistent with our Floor paper, where we claimed that the polar fields are not the dominant factor controlling HMF B. Perhaps indirectly adding to B by determining the CME-rate at minimum [or as Gopal will have it: the other way around…].