Propagation
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Carl Luetzelschwab K9LA

Pass the Humble Pie . . .Or How Good Is Our Old Sunspot Data?

I've given many presentations on the Sun and propagation at many Amateur Radio gatherings. One of the slides I've shown is the maximum smoothed sunspot number of all twenty three solar cycles in our recorded history (it's still too early to include Cycle 24). Figure 1 is the data I've used – and it comes from data readily available in books and at web sites.

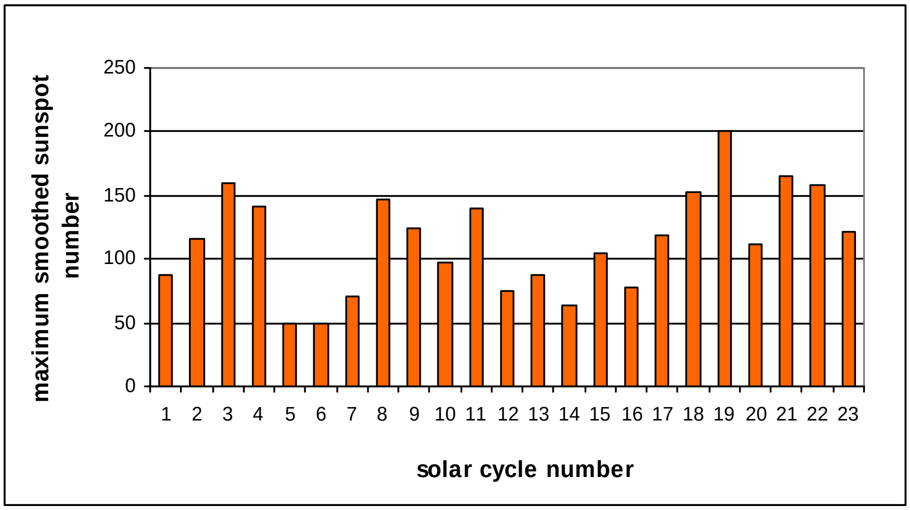

Figure 1 – Maximum smoothed sunspot numbers

From this data I've made three key observations. First, the data is cyclic in nature – we've seen three periods (of several solar cycles) of higher solar activity and two periods (again of several solar cycles) of lower solar activity. Second, based on the first observation, we appear to be headed for a period of smaller solar cycles (Cycle 24 sure appears to be falling in line with this). And third, we've lived through the period of highest solar activity in recorded history – four of the five highest solar cycles have occurred in our lifetime (those four being Cycles 18, 19, 21, and 22).

Those first two observations would stand up in court very well. But that last observation could be iffy depending on how good the data is. So how good is our sunspot data? Well, there are problems with it, and it has to do with the fact that counting sunspots is subjective – there's some human interpretation involved.

The sunspot number is calculated according to the following equation:

$R=K_{Wolf}\ (10G+S)$

where R is the Wolf sunspot number (named for Rudolph Wolf, who devised this equation in 1848), G is the number of sunspot groups, S is the total number of individual spots in all the groups, and K_{Wolf} is a variable scaling factor (usually <1) that indicates the combined effects of observing conditions, the telescope used, and the bias of the solar observers. This equation reflects the importance of sunspot groups as well as of individual sunspots. The Wolf sunspot number has also been known as the Zurich sunspot number and the International sunspot number, and nowadays it is maintained by the SIDC (Solar Influences Data Center) in Brussels, Belgium.

From the last item in the definition of the Wolf sunspot number (the K_{Wolf} factor), it's easy to understand why counting sunspots is subjective. Just the advances in telescopes over the years could affect the count. Then throw in the fact that there have been four official "observers" from 1849 to 1995 (Wolf from 1849-1893, Wolfer from 1876-1928, Brunner from 1929-1944, and Waldmeier from 1995-1995), and you can see trouble brewing.

This issue is attracting much attention lately. There have been several Workshops (sponsored by the National Solar Observatory, the Royal Observatory of Belgium, and the Air Force Research Laboratory) discussing the quality of the old sunspot data, the most recent being last May (2012) in Brussels, Belgium. There was a mini-Workshop held in Sunspot, New Mexico in September 2012 to discuss the issue of possible loss of the smallest sunspots – this is another hot topic in the solar studies field.

Two more Workshops are scheduled for January 2013 (in Tucson, Arizona) and for September 2013 (in Bern, Switzerland). The goal of the September 2013 Workshop is to review the corrected time series of sunspot number from 1610 to the present, and to hopefully reach an agreement amongst all solar scientists so that this new data can be published.

So how did solar scientists come to the conclusion that the old data may have a problem? This started in the early 1990s when Douglas Hoyt and Kenneth Schatten asked the simple question "Do we have the correct reconstruction of solar activity?" Their question came from the problem of counting the number of individual sunspots – as mentioned earlier, the observing conditions, the telescope used and the observer's bias plays a big part in this determination. To get around individual sunspot numbers, Hoyt and Schatten devised the Group Sunspot Number, which is based solely on the number of sunspot groups and normalized by a factor of 12 to match the Wolf numbers from 1874 to 1991.

Hoyt and Schatten found and tabulated many more early sunspot records than were available to Wolf. Unfortunately a fudge factor is also needed in the Group Sunspot Number, and it is designated K_G. Thus the Group Sunspot Number also needs some human interpretation. In equation format, the Group Sunspot Number is $GSN = 12\ K_G\ G$, where G is the number of groups. What this enabled solar scientists to do is divide GSN (the group sunspot number) by R (the Wolf sunspot number). The resultant expectation was 1.00 if the correlation was perfect. If the ratio changed abruptly, that would signify something changed in visually counting sunspots.

The top plot of Figure 2 (from Svalgaard, see the website that is referenced at the end of this column) shows the ratio GSN/R from 1750 to 2000. Note that the Group Sunspot Number is designated Rg in this plot and the Wolf sunspot number is designated Rz in this plot. The bottom plot of Figure 2 shows actual monthly mean data for both sunspot series.

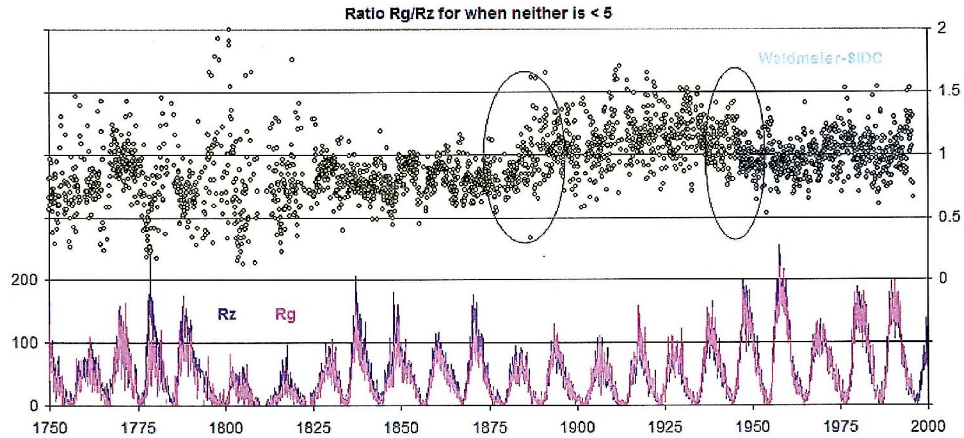

Figure 2 – Original GSN/R ratio and monthly mean sunspot numbers

The most obvious observation from the top plot is the two significant discontinuities around 1946 and around 1885. Something changed in counting sunspots at two different times. The other more subtle observation from the bottom plot is that Cycles 18, 19, 21, and 22 appear to be bigger than all others – except for Cycle 3. This latter observation was mentioned earlier in this column.

The discontinuity around 1946 appears to be due to Waldmeier taking over. What happened was he and his observers began to count the larger spots more than once (weighting according to size), which inflated the sunspot number some 20%. This has continued to the present. This error in the sunspot number has been confirmed based on other solar indices: sunspot areas, calcium II spectral lines, diurnal variations of day-side geomagnetic field activity, and ionospheric critical frequencies foF2.

The discontinuity around 1885 appears to be due to Wolfer reporting more groups than Wolf. This error also has been confirmed using a technique involving geomagnetic activity. Figure 3 (also from Svalgaard, and again see the website that is referenced at the end of this column) is the Figure 2 data corrected for the two errors.

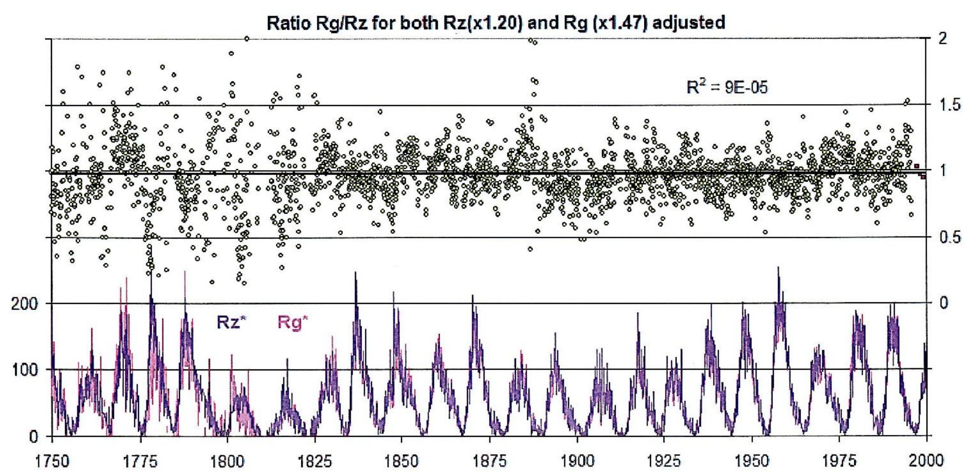

Figure 3 – Corrected GSN/R ratio and monthly mean sunspot numbers

Note that the ratio in the top plot is now scattered about 1.00 with no significant discontinuities. There certainly is more scatter in the early years, but that could be expected due to the more crude techniques back then.

Also note that the monthly mean sunspot numbers of Cycle 18, 19, 21, and 22 in the bottom plot aren't really any bigger than previous cycles. So my last observation in the second paragraph of this column that we've lived through the highest solar activity in recorded history is probably wrong. Although this column is mostly concerned with propagation, think about this conclusion with respect to global warming. Those of you (including me) who thought our recent global temperature rise may have been caused by increased solar activity may need to re-think this.

Let me point out that the corrected data in Figure 3 isn't just a massage of the old data to make it "look better". The corrected data is what solar scientists believe actually happened. For all the details of this interesting topic (and much more information on the Sun), visit Dr. Leif Svalgaard's web site at http://www.leif.org/research/.