Update on Disappearing Sunspots

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This month's column not only gives an update of the May 2011 column with 3 more years of data, but it also presents the data in a different format to see the possible tie to another extended solar minimum period and what could happen to propagation during this period.

Richard Fisher KI6SN, Editor of CQ Plus, forwarded an interesting article that appeared in Forbes magazine (http://www.forbes.com). The title was "*Sun Flatlining Into Grand Minimum, Says Solar Physicist*". The solar physicist referred to is Mark Giampapa, and he is with the National Solar Observatory (NSO) in Tucson, AZ.

Dr. Giampapa's belief that we are entering a grand solar minimum is based on seeing a continuation in the decline of the sunspots' mean magnetic field strengths and a weakening of the polar magnetic fields and subsurface flows.

I've been following this topic since reading the 28 July 2009 issue of EOS, which is the weekly newsletter of the American Geophysical Union (AGU). There was a short article in this issue by W. Livingston and M. Penn (both are also with NSO), and the title was "*Are Sunspots Different During This Solar Minimum?*". The general thrust of the article was that the trend line (a running mean) of the maximum sunspot field strength declined from about 3000 Gauss in early 1992 to about 2100 Gauss in early 2009. Based on the fact that sunspots won't be seen when the field strength is below 1500 Gauss, Livingston and Penn postulated that we won't see any sunspots after 2015. This last sentence gave rise to the phrase "disappearing sunspots" that was reported on extensively.

This article in EOS was actually a brief summary and an update of Dr. Livingston's and Dr. Penn's original paper that appeared in a September 2006 issue of The Astrophysical Journal, the title of which was "*Temporal changes in sunspot umbral magnetic fields and temperatures*". Included in this original article is the explanation of how the magnetic field strength of a sunspot is measured.

Dr. Leif Svalgaard of Stanford University updates the Livingston and Penn data on his web site at http://www.leif.org/research/ in item H. The latest data at the end of 2013 continues to show the declining trend – but there appears to be an ever-so-slight tendency towards a leveling off of the strength. Extrapolating the declining trend line of the latest Livingston and Penn data says we won't be seeing any sunspots around the end of this decade – thus the 2009 prediction of sunspots disappearing by 2015 has moved out at least 5 years.

Now we know that the correlation between the smoothed sunspot number and the smoothed 10.7 cm solar flux is very high (for example, see the figure on the last page of my article "Correlation Between Solar Flux and Sunspot Number" on my website at http://k9la.us/Correlation_Between_Solar_Flux_and_Sunspot_Number.pdf). Thus if we're going to have a problem seeing sunspots due to reduced magnetic field strengths,

we would expect that the correlation between the smoothed sunspot number and smoothed 10.7 cm solar flux would degrade. Let's take a look at this.

Using smoothed sunspot numbers and smoothed 10.7 cm solar flux values from August 1947 (we began measuring 10.7 cm flux in February 1947 – thus the first smoothed value was for August 1947) to the present, the scatter diagram looks like Figure 1.

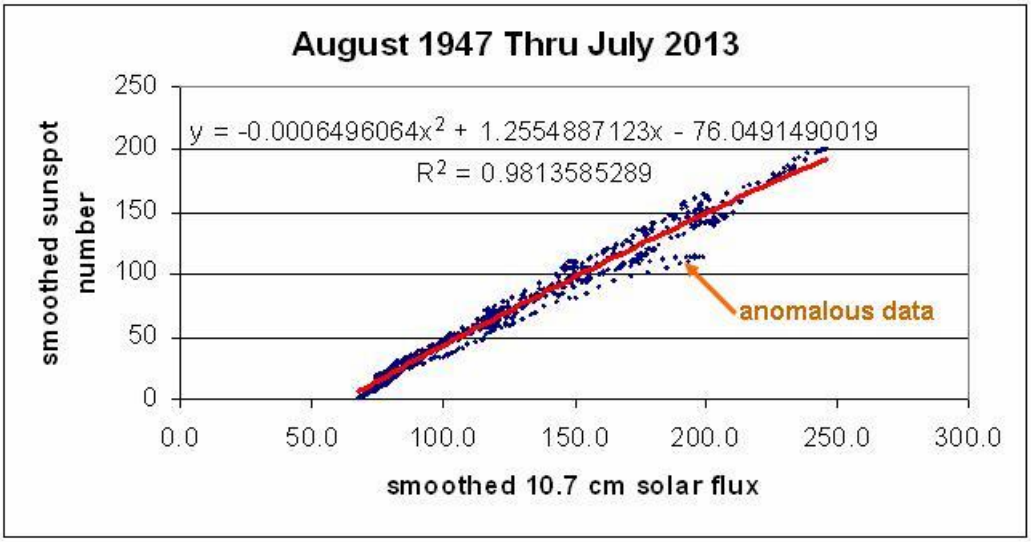

Figure 1 – Correlation with All the Data

The blue dots are the pairs of smoothed 10.7 cm solar flux and smoothed sunspot number data. The red line is a second-order polynomial trend line, with the trend line equation and the R-squared correlation factor annotated on the plot.

Most of the dots fall near the trend line, except for a bunch of dots abnormally below the trend line (annotated in orange). They look out of place and suggest something happened to the correlation between the smoothed 10.7 cm solar flux and the smoothed sunspot number at some point in time.

From Figure 1 and the raw tabular data, it's easy to ascertain that the "problem" started after the first peak of Cycle 23, which occurred in April 2000. So let's do a new scatter diagram for the data from August 1947 to December 2000. Figure 2 does this.

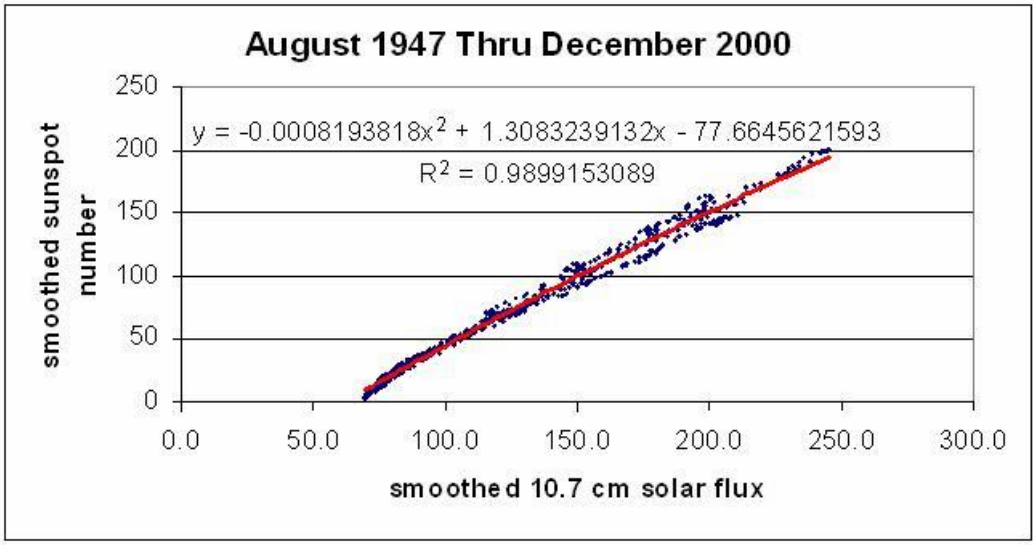

Figure 2 – Correlation for Data to December 2000

The dots that look out of place in Figure 1 are now absent in Figure 2. The R-squared correlation factor is now higher, too. Now what we can do is use the trend line equation in Figure 2 (it calculates the smoothed sunspot number from the smoothed 10.7 cm solar flux) to calculate what the smoothed sunspot number should have been based on the higher correlation between the two from August 1947 to December 2000. See Figure 3.

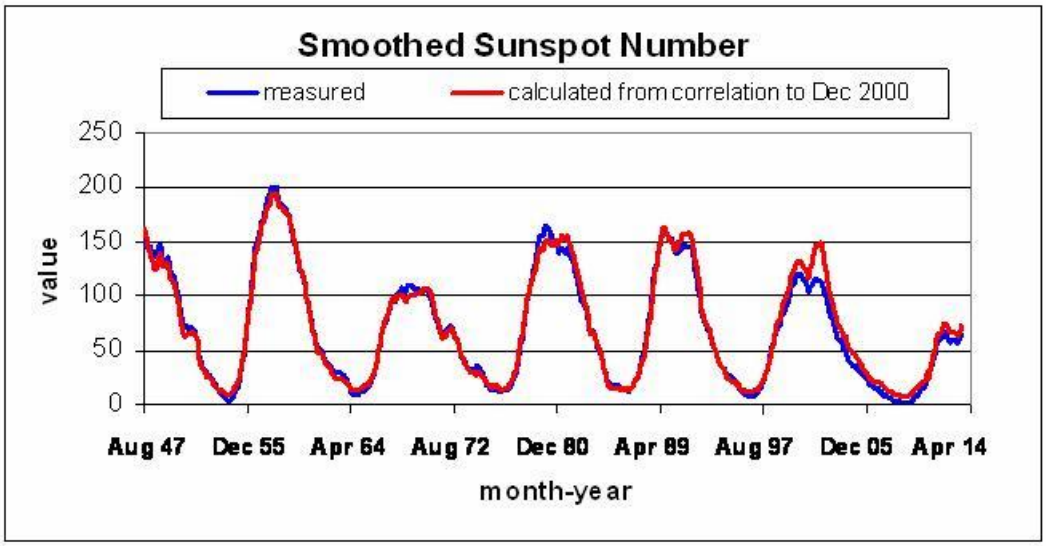

Figure 3 – Measured Sunspots versus Calculated Sunspots

Up until the first peak of Cycle 23, the measured and calculated smoothed sunspot numbers tracked extremely well. Yes, there are discrepancies at the solar maximums, but these are short-term discrepancies. Notice what happened at and after the first peak of Cycle 23 – the measured smoothed sunspot number has consistently fallen short of what was calculated based on the correlation up through December 2000 (this inherently assumes that the smoothed sunspot number changed, not the smoothed 10.7 cm solar flux

– I'll have a comment on that later). So what's happening? Are we starting to not see sunspots as postulated by Livingston and Penn?

If so, is this the signature of entering an extended solar minimum period? Is there any other data that suggests we may be entering another grand solar minimum? Yes, there is, and it is based on what the three solar cycles prior to entering the minimum period do. Although the sunspot data is somewhat sparse, the three solar cycles prior to the Maunder Minimum (1645 – 1715) appear to have had progressively smaller maximum values. That is what is happening now – Cycle 22 was big, Cycle 23 was smaller, and Cycle 24 will be even smaller.

We have to be careful with this sunspot data – Cycles 8, 9 and 10 exhibited the same successive decrease in maximum values, but Cycle 11 was almost as high as Cycle 8. Additionally, the Dalton Minimum (Cycles 5, 6 and 7) was not preceded by three successively smaller cycles.

Although there appears to be more evidence in the sunspot number data that says we're NOT entering another extended solar minimum period, let's assume that we ARE on the verge of entering an extended solar minimum period. Will propagation on the higher bands be nonexistent? To offer an opinion on this, we need to look beyond 10.7 cm solar flux values and sunspot numbers because they are proxies for the true ionizing radiation – UV (ultraviolet) and EUV (extreme ultraviolet).

Thanks to satellites launched in the Space Age, we can measure UV and EUV (we can't measure this radiation at these wavelengths at ground level because it is absorbed in the process of ionization). One of the detectors on board the SOHO (Solar and Heliospheric Observatory) satellite covers 26 – 34 nanometers. Radiation at those wavelengths ionizes about 50% of the F2 region, so it's a good indicator of what the F2 region is doing.

After downloading the 26 – 34 nanometer data (along with a lot of subsequent work), we can plot a scatter diagram of the smoothed 10.7 cm solar flux and the smoothed 26 – 34 nanometer radiation. The 26 – 34 nm data starts in July 1996 and goes thru August 2012. The resulting plot (not shown) shows a similar anomaly as seen in the smoothed 10.7 cm solar flux and smoothed sunspot number data in Figure 1 – there appears to be some outlying data beginning after the peak of Cycle 23. So I looked at data to December 2000, and used the trend line equation to calculate what the 26 – 34 nm EUV should have been. Figure 4 is this data.

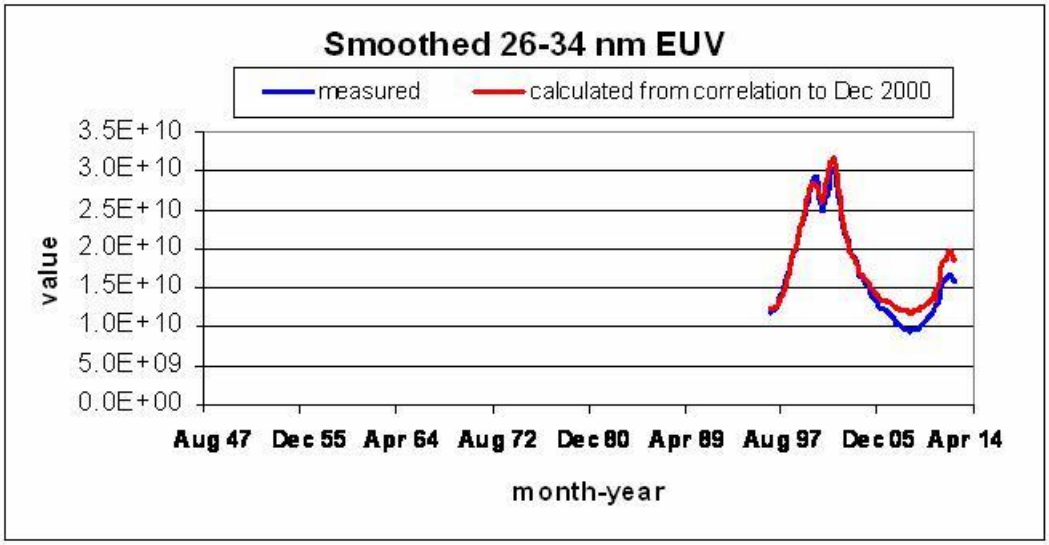

Figure 4 – Measured EUV versus Calculated EUV

What's most obvious is there is much less EUV data available (as expected, since we had to wait for satellites to measure UV and EUV). So any conclusion should be viewed with caution.

The measured smoothed EUV and the calculated smoothed EUV (based on the correlation from July 1996 to December 2000) track very well initially – as they should since we're comparing the measured results against a highly-correlated trend line of the same data. But during the declining phase of Cycle 23, something happened. Either the smoothed 10.7 cm flux didn't change and the smoothed EUV decreased, or the smoothed EUV didn't change and the smoothed 10.7 cm solar flux increased.

This brings us back to the earlier comment with 10.7 cm solar flux and sunspots – we assumed the 10.7 cm solar flux didn't change and it was the sunspot number that decreased. With the additional EUV data, it seems likely that again the 10.7 cm solar flux stayed constant and the EUV decreased – but not as much as sunspots. That makes sense as solar radiation at 10.7 cm is created in the outer solar atmosphere and has nothing to do with solar radiation deeper in the Sun that forms the ionosphere.

So here we are. We have some evidence that we are entering an extended solar minimum period, and we have some evidence that we aren't. We also have evidence that sunspots may be disappearing concurrent with a smaller reduction in EUV. The latter suggests that a Maunder-type Minimum may still offer more F2 region propagation on the higher bands than VOACAP predicts with zero sunspot ('zero sunspots' says 15m would be spotty at best, and 12m and 10m would be noise and no signals). Now that would be interesting.

I can't stress enough that all of this is speculation – we need more data. And we'll get that as we watch what happens in the next 10 or so years (Cycle 24 decline thru Cycle 25 maximum).