Why We Need Smoothed Solar Indices – Part 1

Carl Luetzelschwab K9LA – January 2014

Sunspots have been observed for over 2000 years. The invention of the telescope in the early 1600s allowed permanent records of sunspot activity to be made. Around the middle of the 18th century European astronomers began keeping records on a regular basis. From these records scientists put together the familiar sunspot cycle plot that started with Cycle 1 in 1755, and continues with the present Cycle 24.

The raw data is a daily sunspot number. The data in the early Cycles is sometimes sparse (for example, see Figure 1 in my November 2011 column discussing the possibility of missing an early solar cycle due to insufficient data), but by 1850 (around the peak of Cycle 9) the data was very reliable.

After World War II (in 1947 to be specific) we began measuring 10.7 cm solar flux. The 10.7 cm solar flux is objective (it's a measurement, assuming a calibrated set-up) while visually counting sunspots is subjective (human interpretation required). Just like sunspots, the raw data is a daily 10.7 cm solar flux value.

So why do we need anything more than the daily sunspot number or daily 10.7 cm solar flux? There are two reasons. The first reason has to do with characterizing a solar cycle, which I'll address in this month's column. The second reason has to do with propagation predictions, which I'll address in next month's column.

Figure 1 shows Cycle 23 in terms of the daily sunspot number. The data is very spiky, which simply says the daily sunspot number (and daily 10.7 cm solar flux) are very dynamic. With respect to the figure, three questions to ask are: when did Cycle 23 start, when and how big was the maximum, and when did Cycle 23 end?

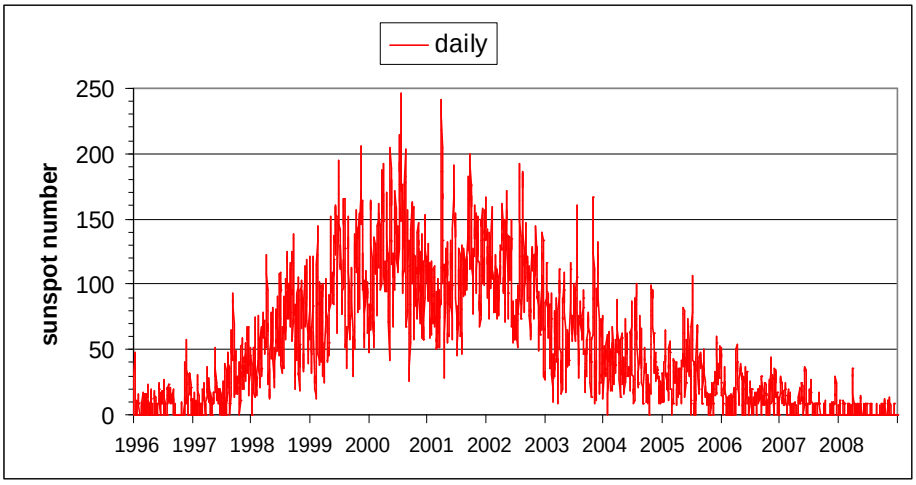

Figure 1 – Cycle 23 daily sunspot numbers

As for the start of Cycle 23, it was likely sometime in 1996. The spiky data precludes pinning this down to a specific month.

As for the maximum of Cycle 23, it kind of looks like there might have been two peaks – one around the middle of 2000 when the sunspot number was almost 250 and another in early 2001 when the sunspot number was around 240. The dip in between these high sunspot numbers also hints at two peaks. But what about the sunspot number around 210 in late 1999? Could this be considered a peak? If so, couldn't the other daily maximums in the sunspot number be considered peaks? So could Cycle 23 have had many peaks?

As for the end of Cycle 23, it's somewhere in the 2008 time frame. Again the spiky data precludes pinning it down to a specific month.

Since we're having trouble pinning down the start and end and the peak (or peaks), let's average the daily values to give us monthly means (remember the mean is the same as the average). Figure 2 is the same data as in Figure 1, but with the monthly means added in dark blue.

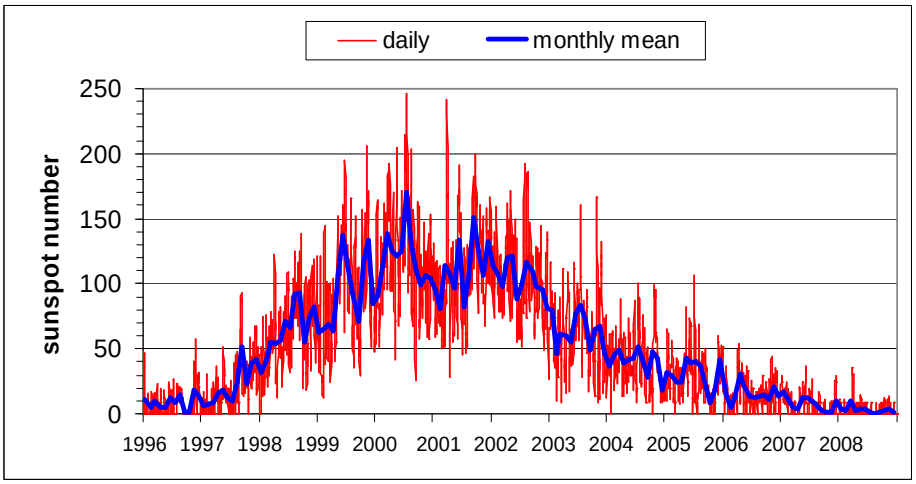

Figure 2 – Cycle 23 daily and monthly mean sunspot numbers

The monthly mean data is still kind of spiky, and does not allow us to pin down the start and end of Cycle 23 to a specific month/year. But at least we can now better see that Cycle 23 appears to have had two broad peaks. With respect to the peaks, should we take the two highest monthly means (about 170 in mid 2000 and about 150 in late 2001) as the peaks? But what about all the other peaks in the monthly mean data – should they figure in somehow?

That last sentence brings us to the use of the smoothed value. The smoothed value for a desired month uses the monthly mean from the desired month, the monthly means from the five months before the desired month, the monthly means from the five months after the desired month, one-half the monthly mean from the sixth month prior to the desired month and one-half the monthly mean from the sixth month after the desired month. Thus the smoothed value is heavily averaged. Also note that the smoothed value is 6 months behind the current month.

The calculation of the smoothed value requires 13 months of data, but using one-half the monthly means at both ends results in twelve full-month data points. This can cause some confusion, as I've seen the smoothed value called a 13-month running average (since 13 months of data is required) and a 12-month running average (since it ends up with 12 full-month data points). Regardless, the smoothed value is heavily averaged – in other words, it is smoothed.

Figure 3 is the same data as in Figure 2, but now with the smoothed values added in green.

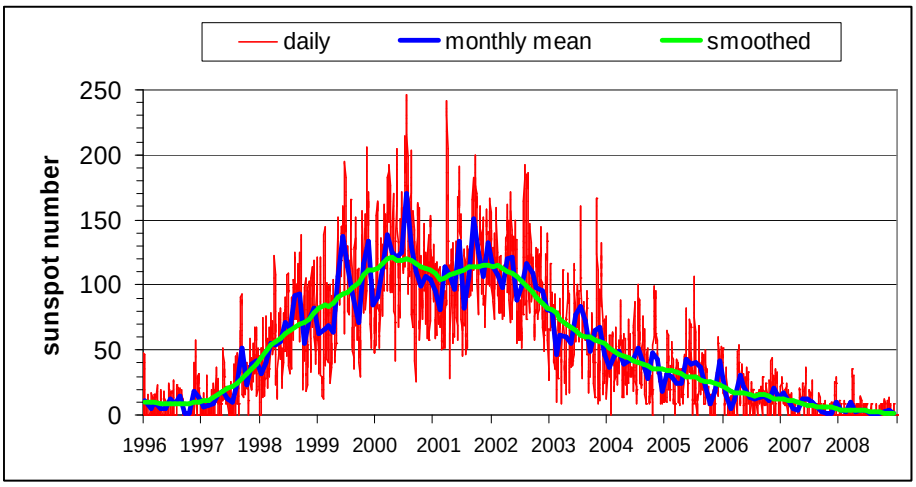

Figure 3 – Cycle 23 daily, monthly and smoothed sunspot number

Now it's easy to see that Cycle 23 did have two broad peaks – one in April 2000 at a smoothed sunspot number of 120.8 and the other in November 2011 at a smoothed sunspot number of 115.5. These months and smoothed values easily come from the raw smoothed data that is used to produce Figure 3.

Now we can also easily determine a likely start and end for Cycle 23. We can simply use the lowest smoothed sunspot number for both. For the start of Cycle 23, May 1996 has the lowest smoothed value (8). For the end of Cycle 23, November 2008 and December 2008 have the lowest smoothed value (1.7). Be advised that these numerical minimums for the start and end times are usually the starting points – the official start and end times of a solar cycle can be revised a bit based on the comparison of old versus new sunspots and other factors.

Although I went through this exercise using sunspot numbers, I could have used 10.7 cm solar flux with the same results – that is, the smoothed value allows us to better determine the start time, the end time and the peak(s) of a solar cycle. This is why the official measurement of a solar cycle is the smoothed value.

This month's column addressed the first reason why we need a smoothed solar index – to best characterize a solar cycle. Stay tuned for next month's column. It will address the

second reason why we need a smoothed solar index – for accurate propagation predictions.