Cycle 24 Is In Uncharted Territory
Carl Luetzelschwab K9LA – March 2015

Cycle 24 will likely have its maximum smoothed sunspot number pegged at 81.9 in April 2014 (remember that solar cycles are officially measured in terms of the smoothed sunspot number). This puts Cycle 24 as the smallest in our lifetimes (which I consider to be Cycle 19 onward) and the smallest since Cycle 16 (Cycle 16, which peaked in early 1928, had a maximum smoothed sunspot number of 78). Thus there's no doubt that we are in uncharted territory with this current solar cycle. But there are other issues that make Cycle 24 unusual. The purpose of this article is to review these other issues.

R_{12} versus F_{12}

For the record, R_{12} is the smoothed sunspot number, which is calculated from thirteen monthly mean sunspot numbers. Similarly, F_{12} is the smoothed 10.7 cm solar flux, which is calculated from thirteen monthly mean 10.7 cm solar flux values. Smoothed values are needed to better see the trend of a solar cycle (the daily values and even the monthly mean values result in a very spiky plot). Smoothed values are also needed because our best understanding of the ionosphere is based on the correlation between monthly median ionospheric parameters and a smoothed solar index (which implies a statistical model of the ionosphere over a month's time frame – we do not have a daily model of the ionosphere).

From the beginning of the measurement of 10.7 cm solar flux in 1947 up through the first peak of Cycle 23, the correlation between the smoothed sunspot number and the smoothed 10.7 cm solar flux has been extremely high. In other words, those two parameters are interchangeable. Figure 1 shows this excellent correlation. Reminder – this high correlation does not apply to daily values or even monthly mean values.

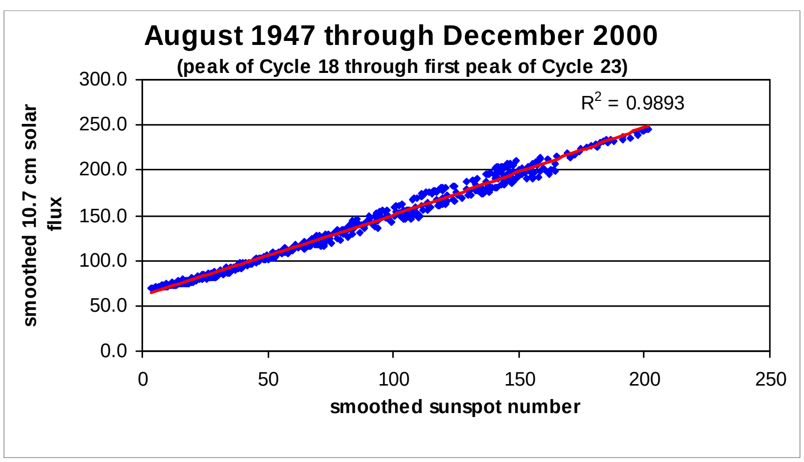

Figure 1 – R_{12} versus F_{12} from 1947 To December 2000

Indeed, the R^2 correlation factor using a second-order polynomial is extremely high. Now let's plot the same data but from the beginning of the measurement of 10.7 cm solar flux in 1947 up through the latest smoothed data. Figure 2 does this.

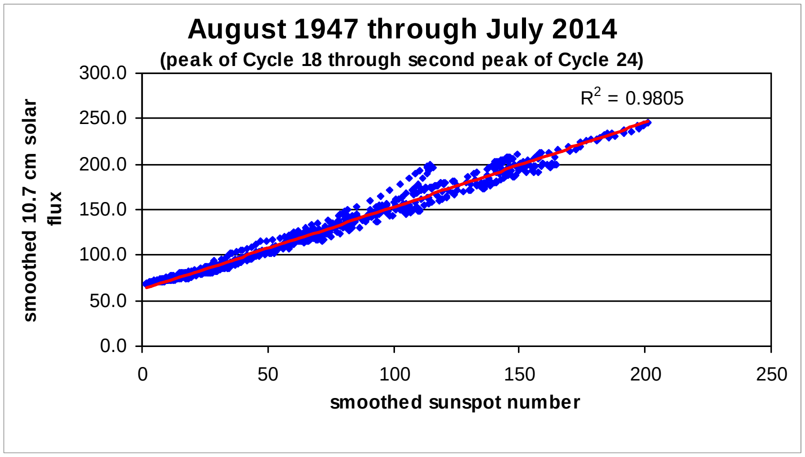

Figure 2 – R_{12} versus F_{12} from 1947 To July 2014

Although the R^2 factor has gone down, it's easy to see that the data after December 2000 results in data points diverging from the trend line in the vicinity of a smoothed 10.7 cm solar flux of 150 to 200. Doing some mental gymnastics indicates that for a given smoothed 10.7 cm solar flux in the range of 150 to 200, the smoothed sunspot number is now lower. It's as if sunspots are disappearing – which brings us to the next issue.

Disappearing sunspots

In July of 2009 two solar scientists (W. Livingston and M. Penn) published a paper showing their measurement of the maximum strength of the magnetic field around sunspots (this is done using the concept of a spectral line splitting in the presence of a magnetic field – it's called Zeeman splitting). Their results are shown in Figure 3.

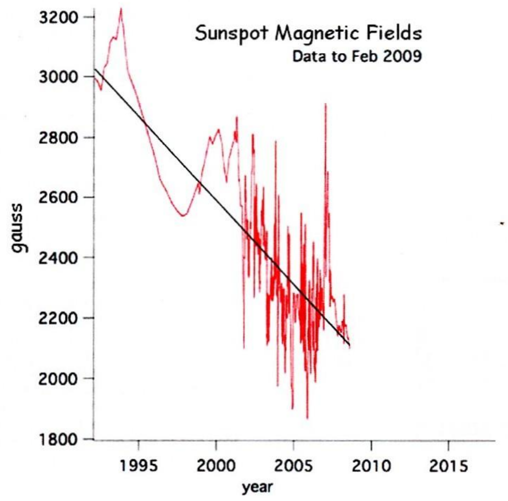

Figure 3- Original Magnetic Field Strength Data

In their paper, Livingston and Penn noted that sunspots are seen when the magnetic field strength is above about 1500 Gauss. Based on that value, extrapolating the linear trend line in Figure 3 suggests sunspots wouldn't be seen toward the end of the decade.

Of course that brought on much talk of the Sun entering another Maunder Minimum period, which was a dearth of sunspots from 1645 to 1715. But updated magnetic field strength data, as shown in Figure 4, suggests that isn't going to happen.

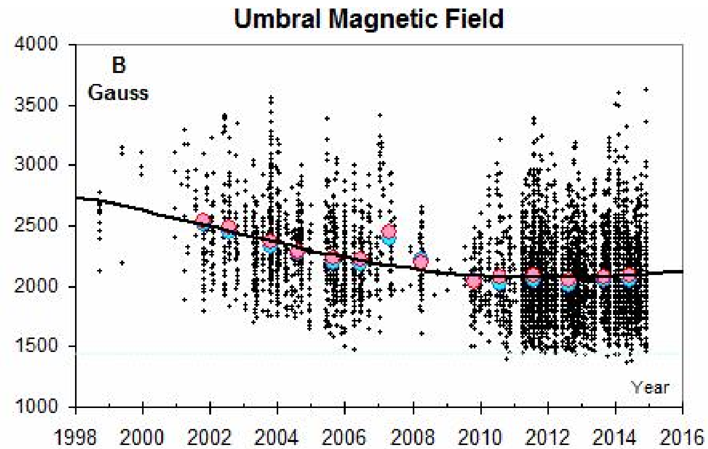

Figure 4 – Updated Magnetic Field Strength Data

Not only has the magnetic field strength bottomed out, it also looks like it is starting to increase. This suggests that we aren't entering another Maunder Minimum, and it also suggests that the degradation of the correlation between R_{12} and F_{12} seen in Figure 2 may be due to *some* sunspots disappearing after the first peak of Cycle 23. Perhaps the high correlation will return.

Two peaks

Cycle 24 gave us two very definite peaks. Cycle 23 also had two very definite peaks, as did Cycle 22 and some earlier solar cycles. Is there a trend in the magnitude of the second peak compared to the first peak? Table 1 gives the maximum of the first and second peaks of Cycles 22, 23 and 24 in terms of both the smoothed sunspot number and the smoothed 10.7 cm solar flux. The green shading in the cells indicates which peak was highest – the first or the second.

	maximum smoothed sunspot number		maximum smoothed 10.7 cm solar flux	
	first peak	second peak	first peak	second peak
Cycle 22	158.5	147.6	213.1	207.7
Cycle 23	120.8	115.5	180.5	197.2
Cycle 24	66.9	81.9	126.8	145.5

Table 1 – Cycle 22, 23 and 24 Properties

In terms of the smoothed sunspot number, the first peak of Cycles 22 and 23 was higher than the second peak. The second peak of Cycle 24 was higher than the first peak.

In terms of the smoothed 10.7 cm solar flux, the first peak of Cycle 22 was higher than the second peak. The second peak of Cycles 23 and 24 was higher than the first peak.

So Cycle 24 is the only solar cycle in recent times that had two peaks with the second peak higher than the first peak in terms of both the smoothed sunspot number and the smoothed 10.7 cm solar flux. What that means is unknown.

Ap vs R_{12}

Ap is the planetary A index (p stands for planetary), and it uses data from mid latitude stations to give us a daily view of the activity of the Earth's magnetic field at mid latitudes.

At solar maximum, where we are right now, Ap is generally higher than at solar minimum. To see this, see Figure 5.

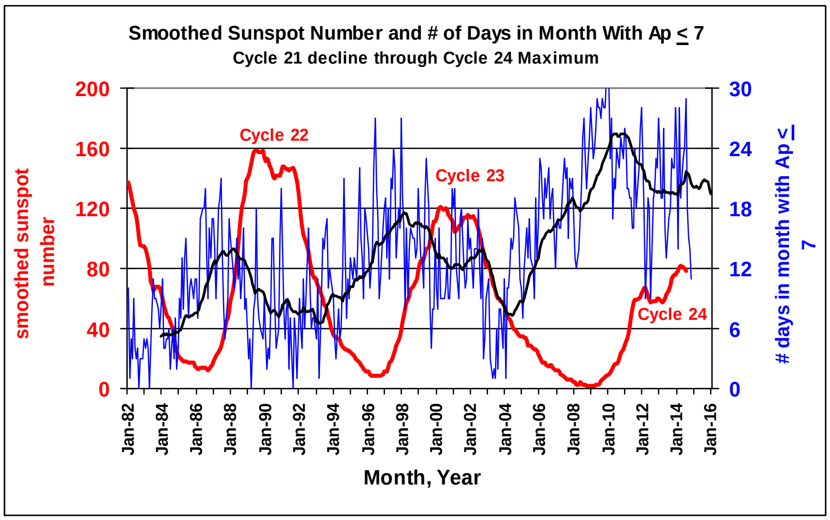

Figure 5 – Ap vs R_{12}

The red line is the smoothed sunspot number, beginning with the decline of Cycle 21 and continuing to the present. The thin blue line is the number of days in the month when the Ap index is less than or equal to 7, signifying quiet geomagnetic conditions. Since the Ap data is very spiky, I've added a black running-average trend line to better see the trends.

What we expect is quiet conditions around solar minimum and disturbed conditions around solar maximum. Indeed, up until the maximum of Cycle 24, the number of days in the month when Ap was less than or equal to 7 maximized (most number of quiet days) at solar minimum and during the rise of a solar cycle. Similarly, the number of days in the month when Ap was less than or equal to 7 minimized (least number of quiet days) at solar maximum and during the decline of a solar cycle.

At Cycle 24 maximum, the number of quiet days in the month did not decrease much around solar maximums as in past solar cycles. This could simply be a sign that Cycle 24's maximum is not a big one.

GCRs vs R_{12}

GCRs (galactic cosmic rays) are mostly energetic protons that come from outside our solar system. As such, they come in from all directions day and night. They result in a shower of secondary particles that can get down to the lower atmosphere. Thus they could have an impact on the electron density in the lower E region, where absorption occurs at night (and there's still enough absorption at night to be detrimental on the lower frequencies).

At solar maximum, the Sun's magnetic field is strongest, and tends to shield our atmosphere from GCRs. Conversely, at solar minimum the Sun's magnetic field is weakest, and tends to let in the most number of GCRs. Thus GCRs arriving at Earth are out of phase with a solar cycle.

The measure of GCRs is the number of detected neutrons, since neutrons are one of the particles in the shower. Figure 6 shows the neutron count from 1965 to the present. The 0 on the vertical axis is the overall average – a positive deviation indicates more neutrons and a negative deviation indicates less neutrons.

Figure 6 – Neutron Count

As expected, the neutron count is out of phase throughout all the data – at solar maximum there are less neutrons and at solar minimum there are more neutrons. The issue here is that the neutron count did not decrease at Cycle 24 maximum as in past solar maximums. The implication here is that there could be more electrons at low altitudes, causing more absorption. This would not be good for 160-Meter propagation.

Summary

We've looked at several issues tied to a solar cycle, and conclude that we appear to be in uncharted territory (at least in our lifetimes) with Cycle 24. Since most of the data only began with the Space Age, we have no idea if what we're seeing now happened in the past when we were entering our other two small-cycle periods (Cycles 5 thru 7 and Cycles 12 thru 16). My guess is these issues have occurred before.