Papers & Presentations:

An Analysis of the Transition From Solar Cycle 24 to Solar Cycle 25

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Abstract

This paper discusses some of the statistics of the transition from solar cycle 24 to solar cycle 25 and analyzes the data based on the size of the active region areas between the years 1874 and 2019, as well as the transition period of large areas between cycles. The analysis shows a modulation of the regular solar cycle activity with, what seems to be, another cycle lasting over 100 years, but does not come to a definite conclusion as to when the current transition will end.

Terminology

The paper refers to active region areas which typically contain one or more sunspots and are measured in the number of millionths of the solar hemisphere. For a more expanded definition, see "SWPC's Users Guide to The Preliminary Report and Forecast of Solar Geophysical Data".

The “Total Daily Active Region Area” identifies the sum of all the individual daily active region areas which are visible on the Sun for a given day.

The total rotation active region areas refers to the sum of all total daily active region areas for a Carrington Rotation.

Presentation

Many of us dream of a Sun full of sunspots, faculae, filaments, plages, and huge prominences around the surface and perimeter of the Sun. Instead, however, we face a Sun with different characteristics. The Sun is currently in the end-phase of solar cycle 24 and the question keeps being raised as to when solar cycle 25 will start. Having had several peaks during solar maximum and the possibility that similar peaks could happen during the solar minimum as well makes this determination even harder.

So the excuse is, "We are approaching solar minimum". That's true, but how does this stack up to a "normal" Sun and other solar cycles? There are many ways to analyze the behavior of our Sun. Scientists use high technology-based instruments to make all kind of measurements and predictions. As amateurs, we decided to use more common and simple ways and considered two methods:

- The Wolf (or Sunspot) number.

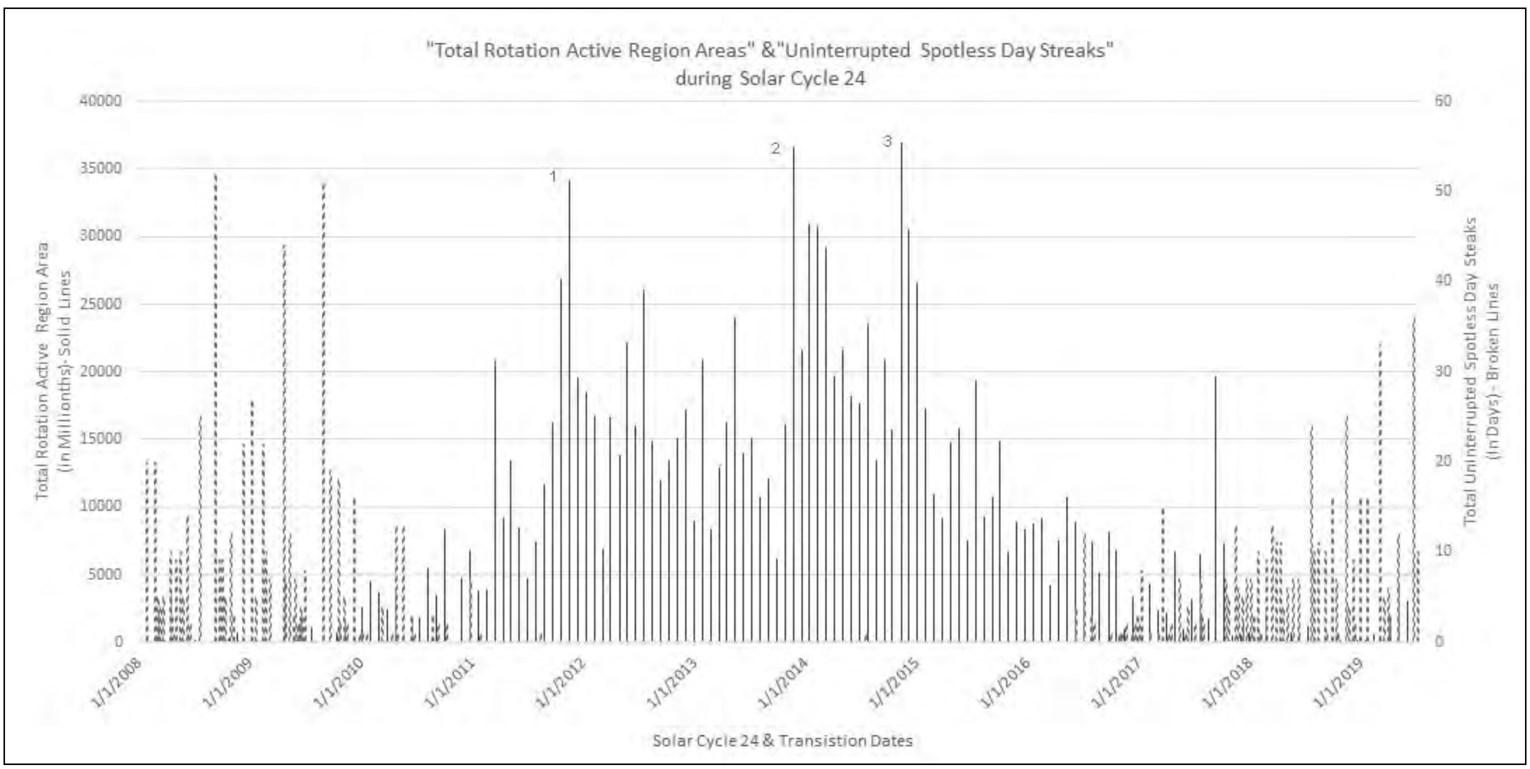

Figure 1

- The size of active region areas or the areas that contain the sunspots.

In the end, we decided to analyze the size of active region areas rather than the sunspot number.

This choice was for several reasons. To start with, the sunspot number (Ri) is generally used in a normalized way, that is, averaged over a period of time. Additionally, in our view, previous research has shown that area sizes show more accurate spontaneous reactions on the Sun and better reflect localized daily activity than sunspot numbers.

In order to shed light onto where we are in the solar cycle, let's first look at the current cycle 24 and its transition to cycle 25. We've been logging data provided by NOAA (National Oceanic and Atmospheric Administration) in its daily GEOA reports (a coded message containing a summary of solar-geophysical activity) into a database and here is what we found.

At first glance, Figure 1 gives a good view of overall solar activity during the period. That is, it shows the total of the daily active region areas for each Carrington Rotation (solid lines in the center of the graph), as well as the streaks of uninterrupted spotless days (broken lines at the outside of the graph). The transition from cycle 23 to 24 showed two long and spotless streaks of respectively 51 and 52 spotless days, as well as a shorter streak representing 44 days.

On the other side, the current transition so far has produced only four "long" streaks of 24, 25, 33 and 36 days, or in other words, only two streaks that lasted longer than a rotation.

Reviewing the size of the active region areas during the cycle shows three peaks, each with gradually decreasing activity. Other than that, the general size of the active region areas during the cycle looks a little higher in the second half of the cycle.

But looking at the rest of the data does not give us great insight into what is happening with the new cycle, and we need to look beyond the current cycle and into the transition between the cycles to find some clues.

In 2008, William Livingston and Matthew Penn predicted that with cycle 24, we were going to enter a new Maunder Minimum, which has not yet happened. However, we see the slow-down of solar activity in the second half of the cycle. So, in order to get a better understanding of this, we used data provided by the SWPC (Space Weather Prediction Center) on the largest sunspot areas, all the way back to the beginning of solar cycle 12 in 1874 up to and including cycle 22.

These active regions covered an area of at least 1,000 millionths of the solar hemisphere. To put the size of these spots into perspective, it is generally assumed that spots over 1,000 millionths can be seen with the naked eye and do not require a telescope, so they are significant in size. We did expand the SWPC information with the same data from cycles 23 and 24, which allowed us to create the graph up to today, as shown in Figure 2. This graph suggests that in addition to the regular 11-year solar cycle, something else may be at work, at least for large sunspots. This resulted in a much higher activity around

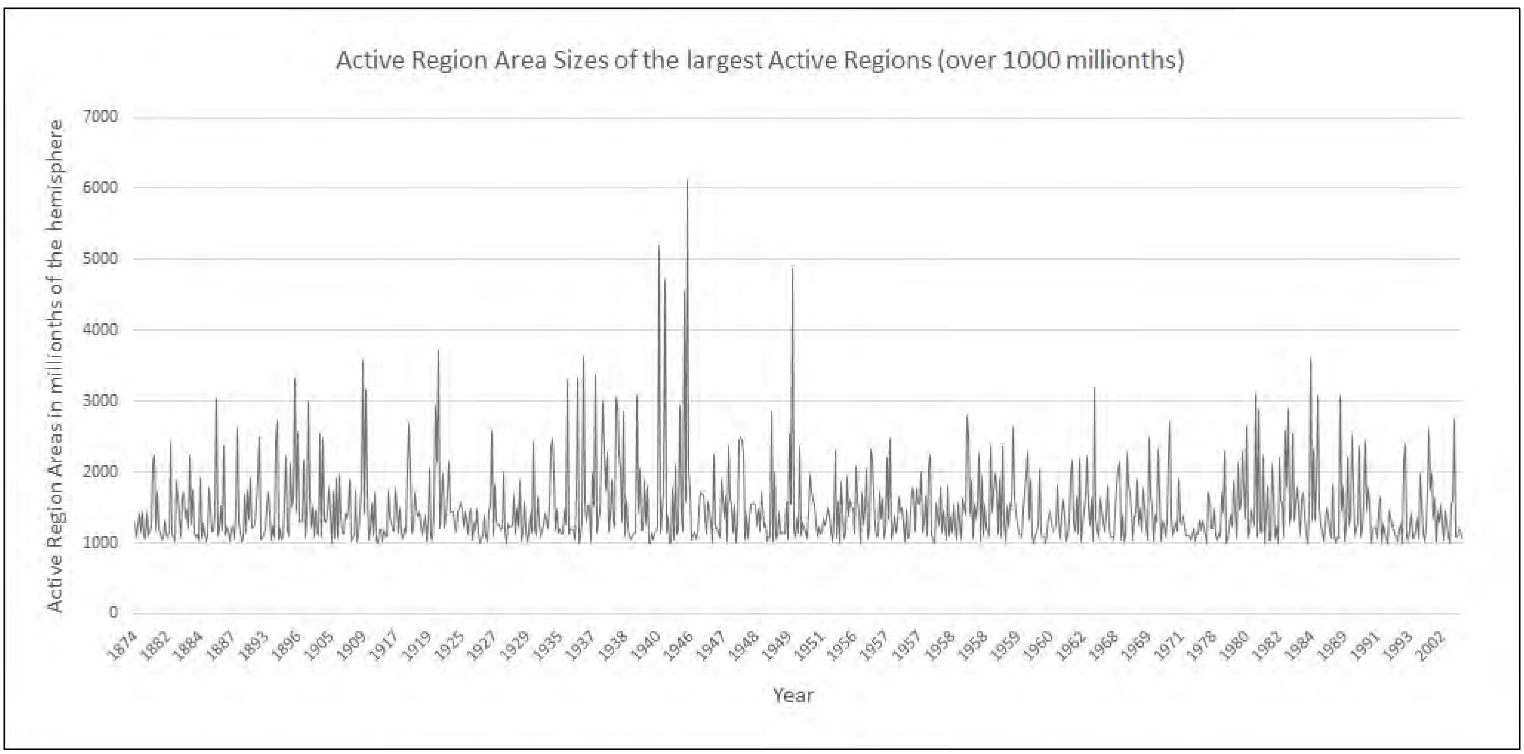

Figure 2

the middle of the last century. But it still does not give us much insight for the current transition.

So we removed the "noise" and looked at the distribution of the number of regions of the solar cycles. The effect of this is shown in Figure 3, where we see a definite increase in the numbers of the regions during those cycles towards the middle of the century. The following decreasing cycles in the second half of the century suggest that the regular solar cycles may be modulated by an additional cycle lasting over 100 years.

Next we analyzed how the larger of the regions were distributed, so we selected only the regions of 2,000 millionths and higher. The regions were classified into groups of 1,000 millionths with the exception of those groups that reached above 5,000 millionths, of which there were two.

One was even larger than 6,100 millionths. We now clearly not only see the effects of a slow moving solar cycle modulating the regular cycles by an increasing number of occurrences, but also an increase of their sizes over time (Figure 4), which showed a peak in solar cycles 17, 18 and 19, followed by a substantial decrease in the subsequent solar cycles.

This also resulted in cycle 24 showing a very small number of these areas so far. Based on the time-frame of this slow moving cycle, it does not look like it is only the 80-year Gleissberg cycle, but another slower moving cycle causing the downward time-frame to extend beyond the 80 years. In fact, for the cycle 24 time period between 2008 and 2019, there was only one area that exceeded the size of 2,000 millionths. It was the well-known active region AR2192 in October 2014.

In addition, the over 2,000 millionths area graph (Figure 4) shows the lowest activity during cycle 24 in almost a century and a half of active regions. However, even as we are at Very Low solar activity levels at the end of cycle 24, this cycle is not yet complete, so we are not able to draw any definite conclusions.

Therefore, to look at this from another perspective, we mapped the transition periods between cycles, specifically the time between the occurrences of large (over 1,000 millionths) active regions (Figure 5). Here we see that the time period between the last of these active region areas during a cycle and the first of these areas in the next cycle substantially increased from one and a half years in the 1930s to about six years for the cycle 23 to cycle 24 transition.

Since cycle 24 is not yet complete, we do not know what this time will be for the current transition. The only thing we know of the current transition is that the last region reaching the threshold of 1,000 millionths happened on September 9, 2017. This was two days after the region in question (AR2673) produced two X-class flares, one of which was an X9.3, the largest flare of the cycle.

Since we do not have data that would show if the long-term cycle causing the up-and-down trend from cycle 12 to cycle 24 has come to its end, we are unable at this time to draw any conclusions on how the current transition will end.

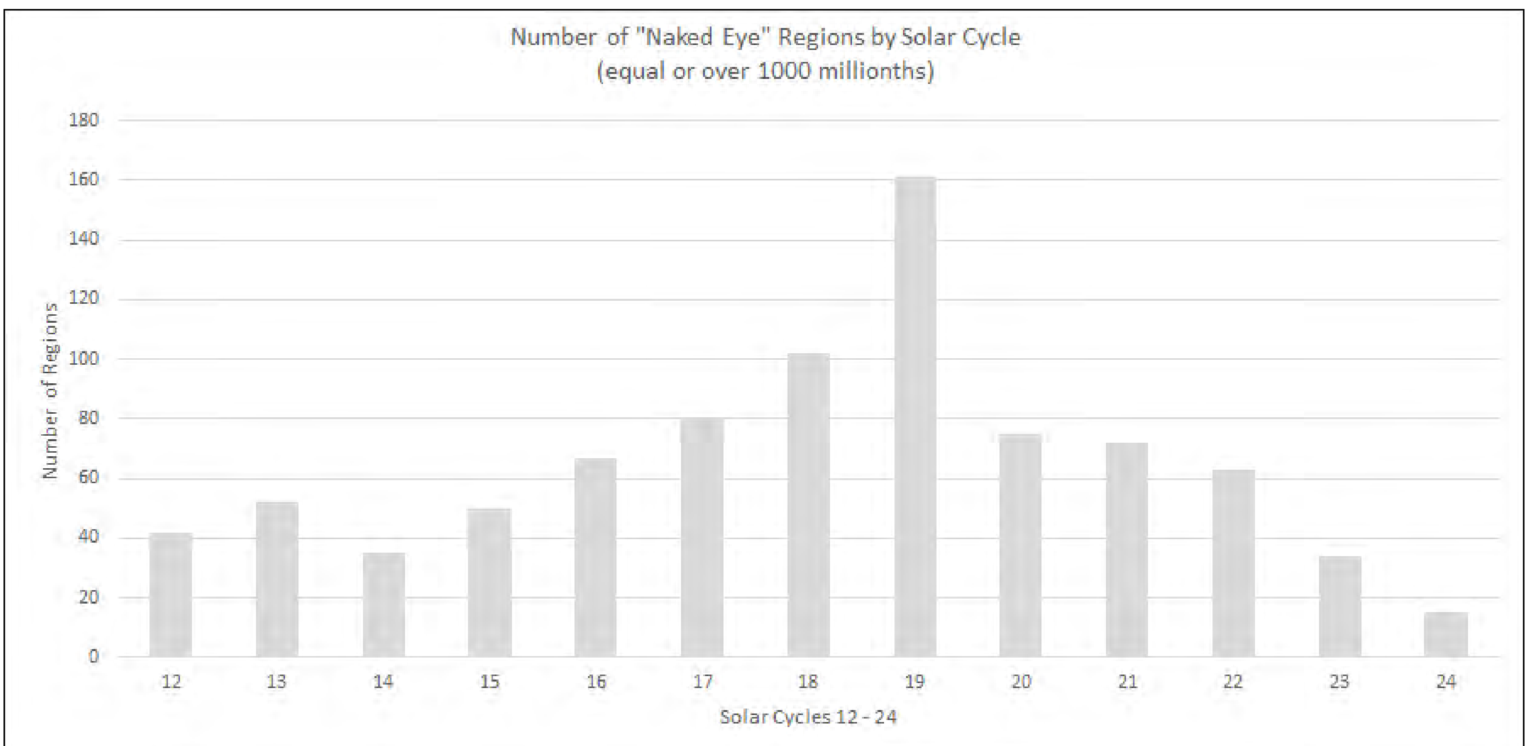

Figure 3

But we can look at how the duration of Cycle 24 stacks up against the duration of the other cycles. Figure 6 shows the length of all Solar cycles since 1874 until today from Solar minimum to the next Solar minimum in years. The one exception is Cycle 24 [which is only shown up to the date of this writing (July 2019)]. For Cycle 24 to equal the time for Cycle 23, we still have a while to go.

Conclusion

We know that the current transition time between over 1,000 millionths regions has already exceeded this transition time identified between cycle 16 to cycle 17 and cycle 18. If the increased cycle 24 - cycle 25 transition time continues as suggested by the upward trend in Figure 5 and Figure 6, it seems we may be in for a prolonged solar low. Or it might be possible that cycle 25 will not have any areas that exceed 2,000 millionth at all.

This is underscored by the fact that the last transition period for the large regions was six years (see Figure 5), and we have not seen a downward peak yet in the current transition. In addition, we have not seen any uninterrupted spotless streaks that lasted substantially longer than a Carrington rotation like at the end of cycle 23.

And lastly, as identified in a previous paper "Are we there yet?", cycle 25 polarized areas, identified by their reverse polarized activity, have been long and far between so far, and very small in size.

Does this mean that this lower activity trend which could not go lower than "spotless" would translate to extending the time period of the solar minimum? It might be that these items suggest that cycle 25 will still be in the making for some time to come.

If, on the other hand, we start seeing the long, spotless streaks and more and larger reversed polarized areas, this may be an indication that the century-long cycle has reversed and an upswing may be in sight.

At this time, we keep monitoring and can only say: Time will tell.

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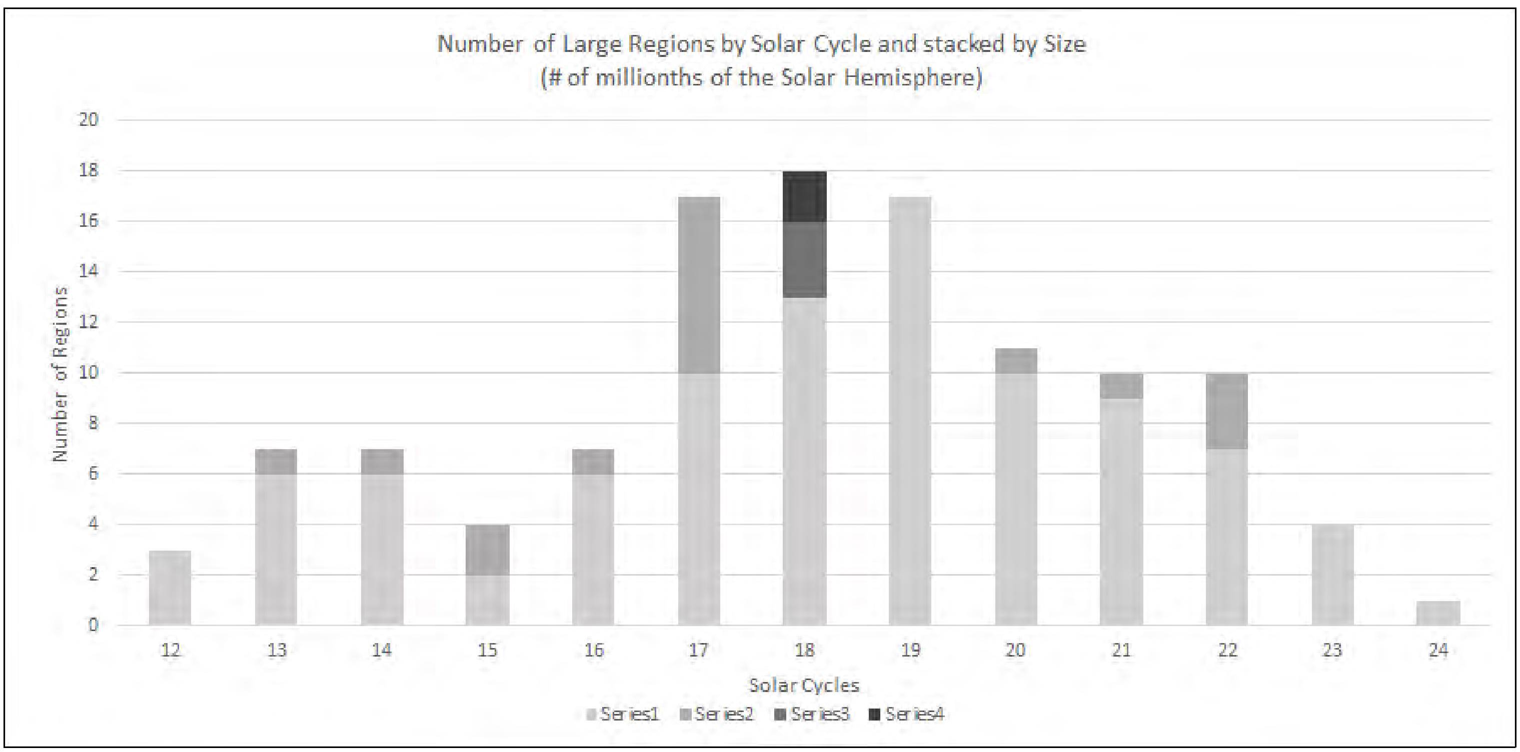

Figure 4

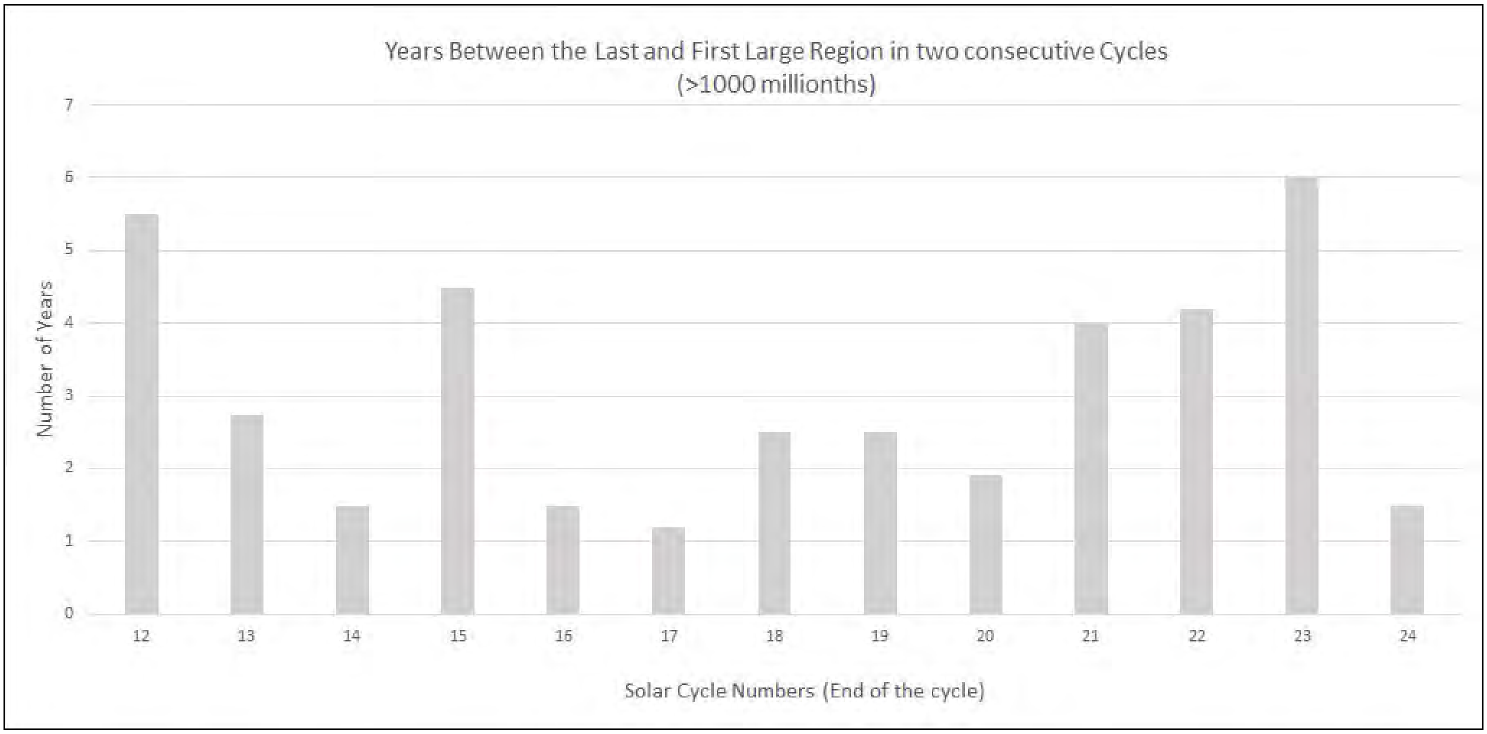

Figure 5

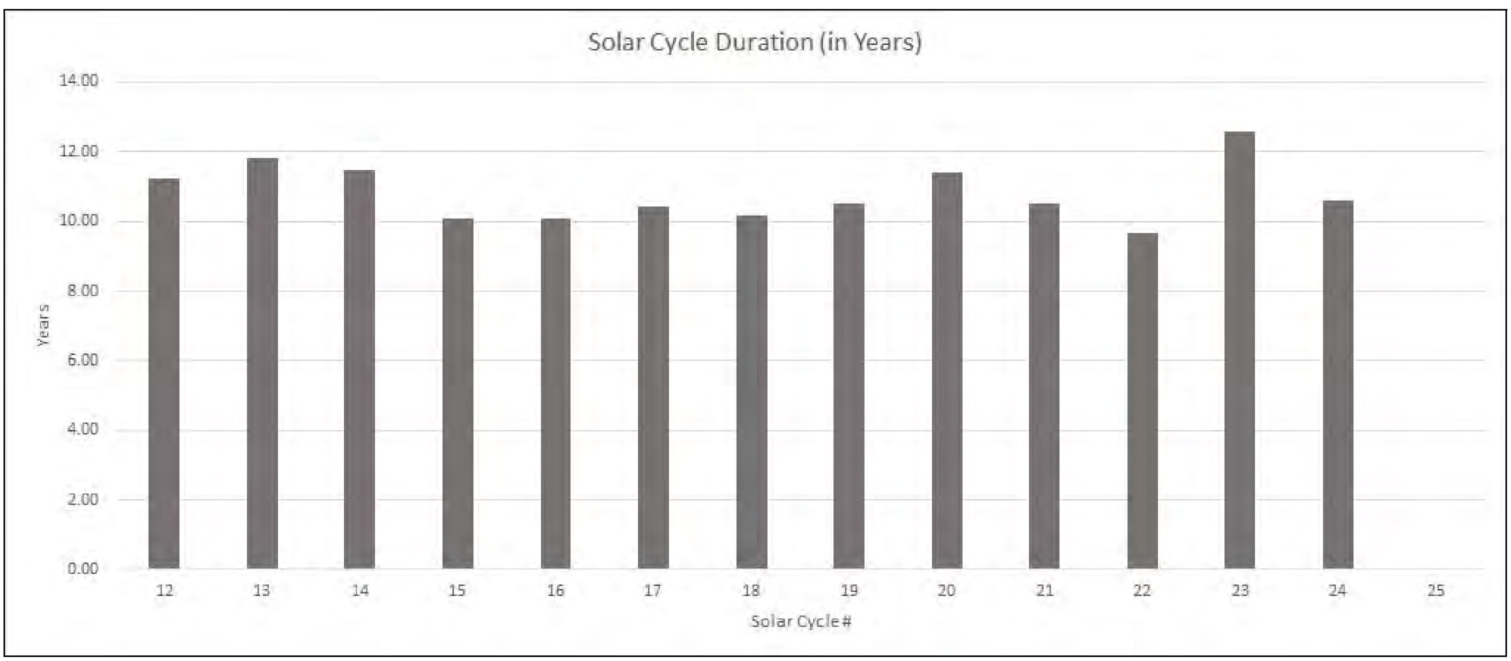

Figure 6