Propagation
WorldRadio November 2011
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Did We Lose a Solar Cycle?

At the Huntsville, Alabama hamfest in August 2009, Dr. David Hathaway (solar scientist at the Marshall Space Flight Center) gave a great presentation about solar cycles. One of his slides showed the monthly mean sunspot numbers for all twenty-three recorded cycles. What made this slide interesting was the fact that it indicated where there were gaps in the data, and thus where assumptions were made about the monthly mean sunspot number. Figure 1 is this data.

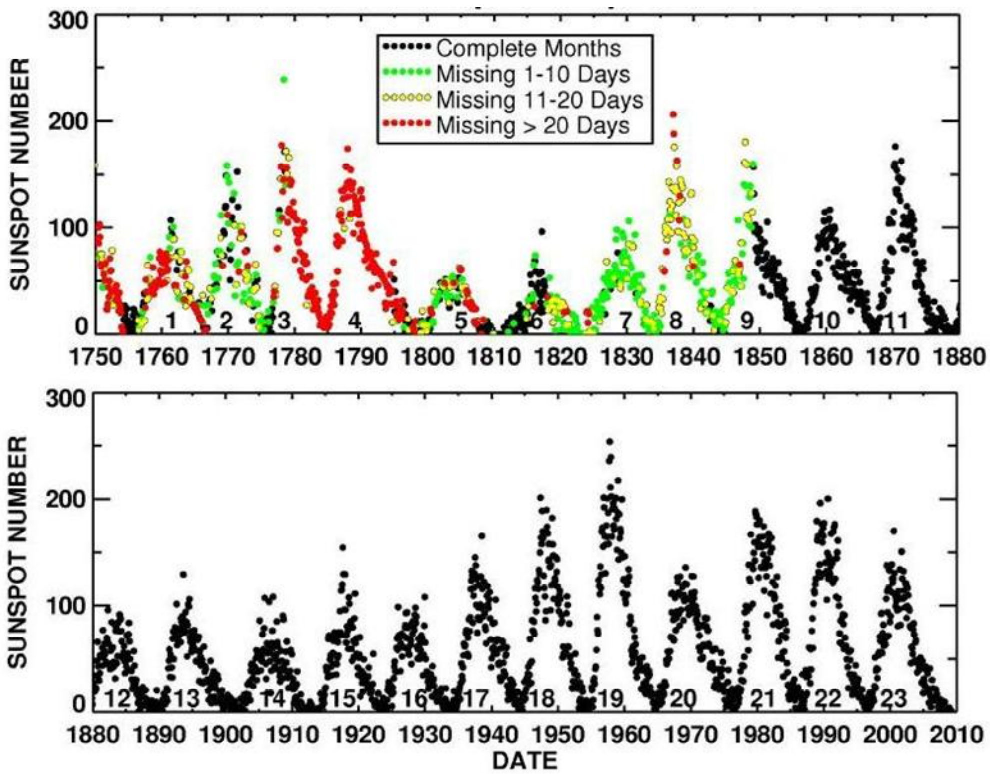

Figure 1 – Monthly Mean Sunspot Numbers with Missing Data

From 1850 onward, we have very good data – it was available on a very consistent basis. But prior to 1850, there has been much missing data and estimates had to be made – especially from about 1780 to 1800 (the beginning of several small cycles referred to as the Dalton minimum). Many of these estimates used geomagnetic field activity as a proxy for sunspot numbers, so these estimates weren't simply wild guesses. But still you have to wonder . . .

This brings us to the purpose of this month's column – did we lose a solar cycle in the 1780 to 1800 time frame? The driving force behind this question is the exceptionally long Cycle 4 – it lasted about 14 years based on a start in 1784 (solar minimum between Cycles 3 and 4) and an end in 1798 (solar minimum between Cycles 4 and 5). Figure 2 shows a histogram of the duration of our twenty-three solar cycles (with the specific solar cycles listed in each vertical column).

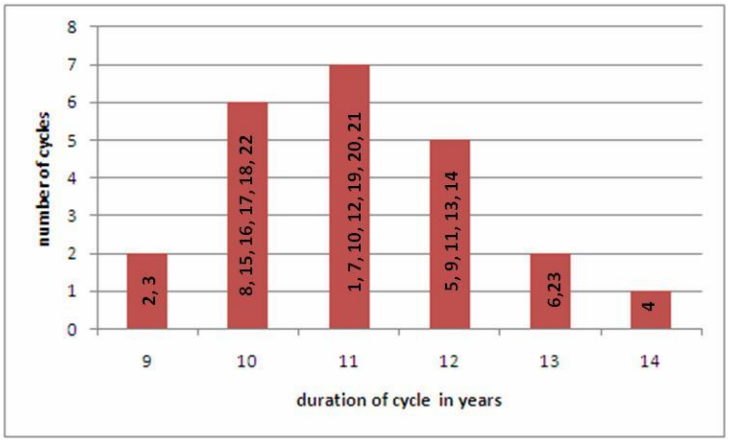

Figure 2 – Solar Cycle Durations

As expected, most of the solar cycles fall in the 10-year, 11-year, and 12-year buckets. Cycle 4, the only one in the 14-year bucket, appears to be an outlier – and thus brings suspicion with respect to the quality of the early data.

So how does one determine if there was just one extremely long cycle from 1784 to 1798, or if there were two shorter cycles? The clue is in the previous paragraph that mentioned a proxy for sunspot numbers. So let's look deeper into proxies.

One of the most obvious proxies for solar activity is indeed geomagnetic field activity. Even though we're lacking magnetic field measurements for the desired time period (the K-index didn't start until 1932, and the antipodal *aa* index goes back even farther but it didn't start until 1868), we can use auroral observations to shed some light on this subject. Figure 3 is a plot of observed auroras per year at high latitudes from 1785 through 1805 (data from I. G. Usoskin, K. Mursula, and G. A. Kovaltsov, *Lost sunspot cycle in the beginning of Dalton minimum: New evidence and consequences*, **Geophysical Research Letters**, Vol 29, No 24, 2002).

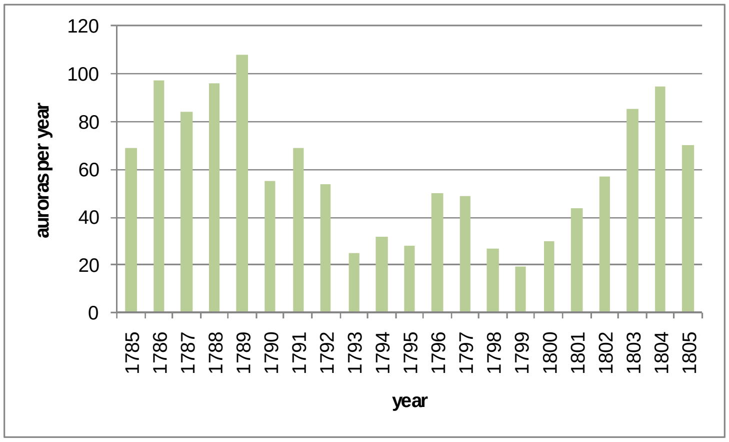

Figure 3 – Auroras Observed Per Year at High Latitudes

From the data in Figure 3 and knowing that there is more auroral activity at solar maximum, we can conclude that there may have been a small solar cycle with a peak around 1796/1797. The peaks in auroral activity of Cycle 4 and Cycle 5 are clearly seen on either side of this alleged smaller peak.

Another proxy for solar activity is cosmogenic isotopes. The deposition of carbon-14 into tree rings and beryllium-10 into ice core samples has given us a long-term picture of solar activity prior to sunspot records. But unfortunately they don't do a very good job of representing short-term solar activity. Thus we can't make any conclusions about a lost solar cycle from this data.

Moving away from solar activity proxies, we can also look at the latitude of emerging sunspots to determine if they're from an old cycle or a new cycle. Sunspots of a new solar cycle usually appear at higher solar latitudes, and as the cycle progresses the sunspots appear at lower and lower latitudes. A diagram of the latitude of where the sunspot emerged versus time is called a butterfly diagram. This, along with the magnetic polarity of a sunspot region, allows solar scientists to ascertain if it's a new-cycle sunspot or an old-cycle sunspot.

Looking at old solar sketches from the pertinent period allows the reconstruction of a butterfly diagram. Figure 4 shows this data for Cycle 3 and Cycle 4 (from I. G. Usokin, K. Mursula, R. Arlt, and G.A. Kovaltsov, *A Solar Cycle Lost in 1793-1800: Early Sunspot Observations Resolve the Old Mystery*, **The Astrophysical Journal**, 700:L154-L157, 2009 August 1).

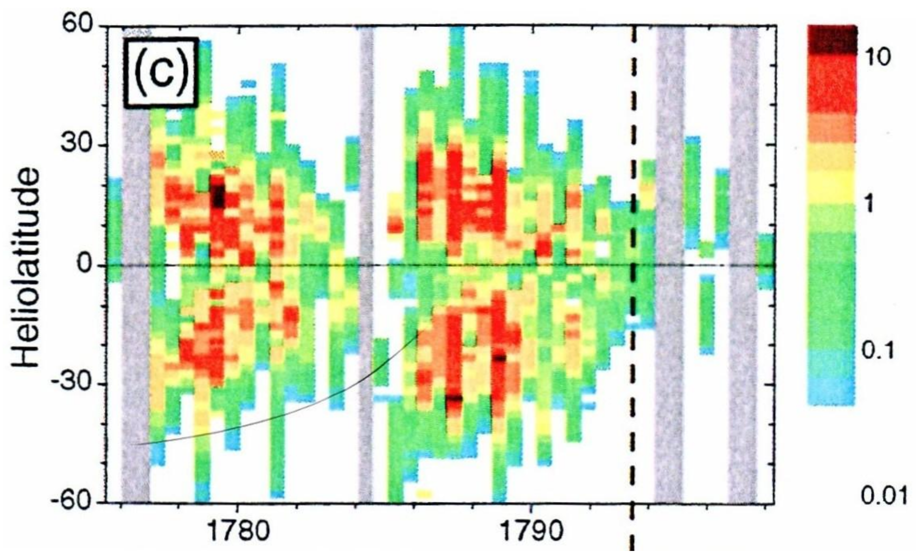

Figure 4 – Reconstructed Butterfly Diagram

Figure 4 shows the density of sunspots, with red being many sunspots. It shows the aforementioned trend – new sunspots from Cycle 24 start out at the higher latitudes around 1784 (with a noticeable southern hemisphere asymmetry), and emerge at lower and lower latitudes until around 1793. Then there's a hint that higher latitude sunspots briefly emerged from 1795 – 1797, suggesting the small lost cycle.

Summarizing all this data says Cycle 4 may have started in 1784 and ended in 1793 (a 9-year duration). Then there may have been a smaller cycle that started in 1793, peaked around 1795 and ended around 1800 (a short 7-year duration).

A good question to ask is “Does discovering this new cycle matter?” I think it does, as we should always strive for accurate data. Additionally, it may be important to have “ground truth” solar data to validate the evolving physical models of the Sun, as it’s interesting to note that some physical models predict the existence of cycles of small amplitude and short duration near a grand minimum (like the Dalton minimum).

Finally, to view Dr. Hathaway’s 2009 presentation (20090815_Hamfest.ppt), along with others he has given, visit **http://solarscience.msfc.nasa.gov/presentations/**. Also, for general information on solar cycles and their characteristics, I recommend his paper titled The Solar Cycle, which is available at **http://www.livingreviews.org/lrsp-2010-1**.