Relating the Start to the Terminator of Solar Cycle 25 and a Significant X-Flare event

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Abstract

After analyzing the lowest adjusted 10.7cm solar flux values, we find that the adjusted flux for October 2019 is low enough to locate the start of Solar Cycle 25 between August 2019 and January 2020. Further findings point to November-December 2019 as the starting date for Solar Cycle 25, while the 2K high (based on 2048x2048 pixels SDO images) resolution sunspot number points to December 2019. Once we understand the signal for the start of Solar Cycle 25, we can deduce the start of the time frame for the 'Terminator'. This is the moment when Cycle 25 will be 'fired up'. Two recent articles made headlines using complex mathematics to predict the start of the 'Terminator'. However, at the time they didn't know the start of Solar Cycle 25 and therefore failed in their effort. The reason for this is that the low point between cycles is currently considered unimportant. We strongly disagree and point out that we can calculate the 'Terminator' more accurately if the low is considered a crucial starting point. A possible significant solar flare event in excess of >x10.0 could happen in 2021.

Keywords

Sunspot cycle 25; Low sunspot activity; Terminator; Polar fields Sun; 10.7cm Solar flux; High resolution sunspots

1.0 Introduction

It is known that the solar radio flux is strongly correlated to the sunspot cycle (Clette et al),2016, as shown by formulas calculating the solar flux from the sunspot number http://www.sidc.be/silso/datafiles and vice versa (Johnson R.W.). The longest standing database of the 10.7 cm solar flux is from http://www.spaceweather.ca/solarflux/sx-5-mavg-en.php spaceweather.gc.ca, which goes back to 1947, and contains three metrics. While the observed flux is measured, the adjusted and absolute flux values are calculated from it.

The annual correction to the flux arising from the Earth's orbital eccentricity is discussed in relation to the 10.7 cm flux on page 103 of "Physics of the Earth's Space Environment: an introduction" by Gerd Prölss, 2004**.** Because there is a difference in radiation due to the varying distance between the Earth and the Sun, the values must be adjusted to the mean distance of 1 AU for a correlation with sunspot cycles (Prölss, Gerd).
There are no papers which discuss if the observed or adjusted flux is to be preferred. Only the technical paper from Tapping K.F. , 2013, discusses in section 4.2.2. that if flux values are being compared with sunspot numbers, the modulation needs to be corrected to a constant Earth-Sun distance of 1 AU. This is done automatically by the computers which control the flux monitors with built-in ephemeris at the time of the measurement, otherwise differences of up to 7 percent would be found. If you subtract the adjusted flux from the observed flux , as shown in Figure 1, then the influences from the varying Sun-Earth distance appear.

Figure 1: Adjusted solar 10.7 cm flux subtracted from observed flux

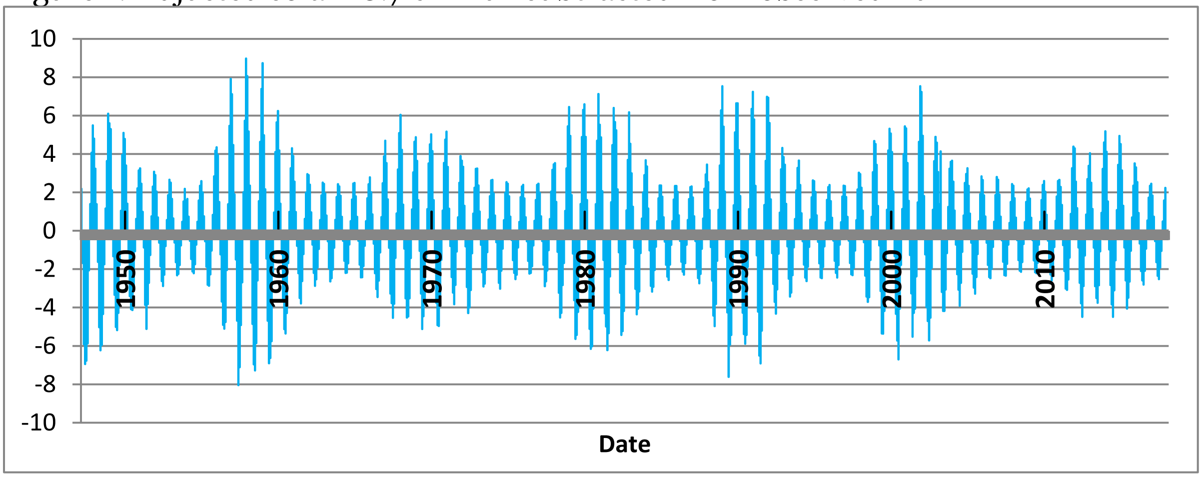

Figure 1. March 1947 – December 2017. Adjusted flux subtracted from the observed flux. We find almost the same values to both sides of the horizontal axis and a wave pattern shows up related to the sunspot cycle. The +/- 11 year modulation is simply due to the Solar Cycle: 7% of 70 sfu equals about 5 sfu during solar minimum, as shown by the curve (-2.5 to +2.5).

Source 10.7cm radio flux values (sfu): World Data Center for Solar-Terrestrial Physics, Moscow

The solar flux values from Penticton are measured automatically. Faults due to solar flares and other disturbances are not corrected. Therefore, we use the values from the http://www.wdcb.ru/stp/data/solar.act/flux10.7/ World Data Center for Solar-Terrestrial Physics, Moscow and also these from "Solar Terrestrial Activity Report" or STAR http://www.solen.info/solar/

2.0 Correlation between lowest adjusted and observed solar flux and the start of a new sunspot cycle

Table 1 shows a comparison between the lowest solar flux values at, after, or in the months preceding the start of a new cycle: the values for the lowest adjusted flux take place within maximum 3 months from the start of a new Solar Cycle. In October 2019 the adjusted flux (67.0) was the same like the start of Solar Cycle 24.

Cycle number	Start cycle	Adjusted flux		Observed flux	
	Date	Date	sfu	Date	sfu
19	1954/04	1954/01	66.5	1954/06	67.3
20	1964/10	1964/07	69.2	1964/07	67.0
21	1976/03	1976/02	68.8	1976/07	67.5
22	1986/09	1986/09	69.4	1986/06	67.6
23	1996/08	1996/10	68.7	1996/10	69.2
24	2008/12	2008/12	67.0	2008/07	65.7
25	2019/08-2020/01	2019/10	67.0	2019/08	67.0

Until now the lowest adjusted flux was 66.5 in January 1954. However, there were only 22 recorded days in January 1954, so this value has to be eliminated. The second lowest value equals 67.0 in December 2008. This is the same value as measured in October 2019. Therefore, our claim that this value is low enough to be considered the start of a new Cycle.

Source 10.7cm radio flux values (sfu): World Data Center for Solar-Terrestrial Physics, Moscow
Source 10.7cm radio flux values (sfu): "Solar Terrestrial Activity Report" or STAR

2.1 Lowest observed solar flux and start sunspot cycle

The list below shows the month with the lowest observed solar flux compared with the start of a sunspot cycle. It fluctuates between 4 months late and 5 months early. This is a 9 month time frame, which is too large to pinpoint the start of a Solar Cycle:
Cycle 19: 2 months late
Cycle 20: 3 months early
Cycle 21: 4 months late
Cycle 22: 3 months early
Cycle 23: 2 months late
Cycle 24: 5 months early
Cycle 25: 4 months late = May 2019
5 months early = January 2020

Because the 9 month time frame is much larger than the 5 month time frame with the adjusted flux as can be seen in point 2.2, we eliminate the observed flux as a predictor for the start of a new Solar Cycle. The discrepancy between the 2 values also proofs that the adjusted flux is the preferred value to compare it with the start of Solar Cycles.

2.2 Lowest adjusted solar flux and start sunspot cycle

The list below shows the month with the lowest adjusted solar flux compared with the start of a sunspot cycle:
Cycle 19: 3 months early
Cycle 20: 3 months early
Cycle 21: 1 month early
Cycle 22: exact
Cycle 23: 2 months late
Cycle 24: exact
Cycle 25: if we take 2 months late = August 2019
If we take 3 months early = January 2020

3.0 A marker for the start of a new sunspot cycle

After studying these findings, we searched for a formula that describes the relationship between the solar flux and the sunspot cycle. With only 2 variables, the 10.7 cm flux and the start of sunspot cycles, the possibilities were limited. After dividing the smoothed adjusted flux by the smoothed monthly mean sunspot number, we found a usable predictor for the start of a new sunspot cycle.

3.1 Formula for the start of a new sunspot cycle from smoothed values

The following formula approximates the start of a new sunspot cycle:
(SMMAF/SMMSN -1)*10+100
With:
SMMAF = smoothed monthly mean adjusted flux
SMMSN = smoothed monthly mean sunspot number

The formula is presented in figure 2 and table 2.

Figure 2 shows the difference between the smoothed adjusted flux and the smoothed sunspot number:

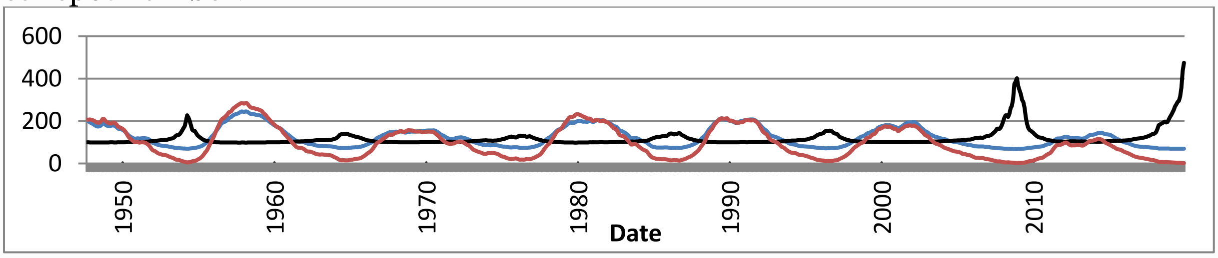

Figure 2: September 1947 – December 2019.

Black line = strength between smoothed mean adjusted flux divided by smoothed mean sunspot number.
Red line = smoothed monthly mean sunspot number (SMMSN)
Blue line = smoothed monthly mean adjusted flux (SMMAF)

Sunspot data from the World Data Center SILSO, Royal Observatory of Belgium, Brussels.
Source 10.7cm radio flux values (sfu): World Data Center for Solar-Terrestrial Physics, Moscow
Source 10.7cm radio flux values (sfu): "Solar Terrestrial Activity Report" or STAR

Table 2 shows the strength in relation with the start of sunspot cycles:

Cycle number	**Start Solar Cycle**	**Highest strength smoothed adjusted flux divided by smoothed sunspot number**	
	Date	**Date**	**Strength**
19	1954/04	1954/04	226.6
20	1964/10	1964/10	140.7
21	1976/03	1976/03	131.6
22	1986/09	1986/09	144.0
23	1996/08	1996/08	154.3
24	2008/12	2008/12	401.3
25	2019/12	2019/12	474.9

The list below shows how the prediction using the formula under 3.1 predicts the start of a sunspot cycle:

Cycle 19: exact
Cycle 20: exact
Cycle 21: exact
Cycle 22: exact
Cycle 23: exact
Cycle 24: exact
Cycle 25: value from December 2019 is highest ever since start flux measurement.

We can conclude that there is a nearly 100 percent correlation between the smoothed adjusted flux and the start of a new sunspot cycle.

4.0 Formula for the start of a new sunspot cycle from centered month + 6 months preceding while using a half (1/2) for the first month

The formula presented in this section tries to mimic the smoothed sunspot number as a forward-looking indicator. The formula presented makes use of smoothing of values. The formula used for smoothing is the following:

$$[(n1/2) + (n2+n3+n4+n5+n6+n7+n8+n9+n10+n11+n12) + (n13/2)]/12$$

where ni = value for month i, with i=1 to 13, 13 being the most recent month.

As an example, the formula for calculating the smoothed value for August 2018 adds half of the Feb 2018 value plus the sum of the April through Jan 2019 values plus half of the Feb 2019 value and divide the sum by twelve. (where n1 = value for Feb 2018, n7 = value for August 2018 and n13 = value for Feb 2019)

Our formula for the forward looking smoothed sunspot number and smoothed flux number equals:

$$[(n1/2)+(n2+n3+n4+n5+n6+n7)]/6$$

Remark: we divide by 6 and not by 6.5 because we found that it resembles more accurately the values of the 13 month smoothed number.

(where n1 = value for August 2018, n7 = value for February 2019)

Using the above smoothing, we define the following Strength Factor (SF) for:

$$SF = (CMMAF6/CMMSN6-1)*10+100$$

With:
CMMAF6 = centered month mean adjusted flux + 6 months preceding (½ first month) divided by 6

CMMSN6 = centered month mean sunspot number + 6 months preceding (½ first month) divided by 6

The results from applying this formula are presented in figure 3 and table 3.

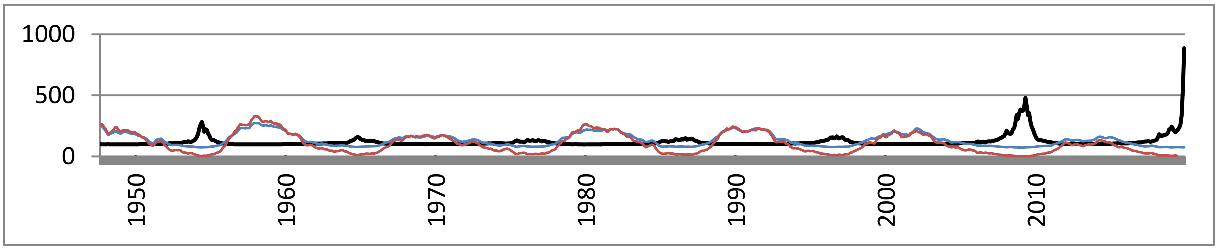

Figure 3. CMMAF6 and CMMSN6 for the period September 1947 – December 2019. Black line = strength between centered adjusted flux + 6 months preceding (½ first month) divided by centered sunspot number + 6 months preceding (½ first month)
Red line = centered month mean sunspot number + 6 months preceding (½ first month) divided by 6 (CMMSN6)
Blue line = centered month mean adjusted flux + 6 months preceding (½ first month) divided by 6 (CMMAF6)
Sunspot data from the World Data Center SILSO, Royal Observatory of Belgium, Brussels.
Source 10.7cm radio flux values (sfu): World Data Center for Solar-Terrestrial Physics, Moscow
Source 10.7cm radio flux values (sfu): "Solar Terrestrial Activity Report" or STAR

Table 3 shows the highest strength between centered adjusted flux + 6 months preceding (½ first month) divided by centered sunspot number + 6 months preceding (½ first month in relation with the start of sunspot cycles.

Cycle number	**Start cycle**	**Centered month + 6 months preceding (½ first month) divided by 6**		**Centered month + 6 months preceding (½ first month) divided by 6**	
				2K	**1K**
	Date	**Date**	**SF**	**SF**	**SF**
19	1954/04	1954/06	282.5		
20	1964/10	1964/11	159.6		
21	1976/03	1976/07	132.9*		
22	1986/09	1986/09	149.4		
23	1996/08	1996/10	164.2		
24	2008/12	2009/05	479.1		
25		2019/09	257.2	142.7	190.1
		2019/10	334.3	150.9	215.6
		2019/11	560.3	153.8	237.7
		2019/12	901.2	157.3	260.6
		2020/01	509.0	149.7	226.9

Table 3: Strength Factor between CMMAF6 divided by CMMSN6 in relation with the start of sunspot cycles

*The Strength Factor was 132.8 on 1976/03
The high resolution 1K (1024x1024 pixels SDO compressed image) and 2K (2048x2048 pixels SDO compressed image) sunspot number from Solar Terrestrial Activity Report give a similar result as the ISN.

The list below shows how the prediction using the formula under section 4.0 predicts the start of a Solar Cycle:
Cycle 19: 2 months late
Cycle 20: 1 month late
Cycle 21: 4 months late (but value on exact start was only 0.1 lower)
Cycle 22: exact
Cycle 23: 2 months late
Cycle 24: 5 months late
Cycle 25: exact - 5 months late

The above formula gave in all 6 previous cases a positive or exact result at the start or after it happened according to the International Sunspot Number, and not before. Sometimes it gave a too early signal, but the current highest strength from December 2019 should be the correct one and we can say Solar Cycle 25 started in July–December 2019 (exact to 5 months late). The high resolution sunspot numbers give the same result.

5.0 Difference fitted vs mean sunspot number and the start of a new Solar Cycle

We discovered another indicator to find the start of a Solar Cycle. It concerns a huge discrepancy between the fitted and measured sunspot number, in a time frame between 5 months before and 6 months after the start of a new cycle, indicating a new cycle has started. We use the formula from Geryl and Alvestad, 2020, to calculate the difference between the fitted and measured sunspot number. The results are presented in table 4.

Table 4 shows the highest differences before and after the start of a Solar Cycle

Cycle number	Start cycle	Difference fitted vs mean sunspot number before start cycle		Difference fitted vs mean sunspot number after start cycle	
	Date	Date	% SSN	Date	% SSN
19	1954/04	1954/01	-89.8	1954/06	-95.3
20	1964/10	1964/07	-41.4	1965/04	-24.7
21	1976/03	1975/10	-23.6	1976/07	-68.3
22	1986/09	1986/06	-93.3	1987/02	-62.8
23	1996/08	1996/05	-37.3	1996/10	-90.5
24	2008/12	2008/08	-95.2	2009/03	-91.7
25	2019/11-12	2019/08	-93.2	2020/02	-97.6

Difference fitted vs mean sunspot number before start cycle:
Cycle 19: 3 months early
Cycle 20: 3 months early
Cycle 21: 5 months early
Cycle 22: 3 months early
Cycle 23: 3 months early
Cycle 24: 4 months early
Cycle 25: 3 to 5 months early or between November 2019–January 2020

Difference fitted vs mean sunspot number after start cycle:
Cycle 19: 2 months late
Cycle 20: 6 months late
Cycle 21: 4 months late
Cycle 22: 5 months late
Cycle 23: 2 months late
Cycle 24: 3 months late
Cycle 25: 2 to 6 months late or between August-December 2019

We notice that the overlapping period of the two approaches for the start of Cycle 25 is November-December 2019.

6.0 Sunspot number from start date and in the 6 months preceding and after the start of each cycle

We calculated the mean smoothed sunspot number using 6.5 months as shown in section 4.0. This mimics the smoothed sunspot number. As can be seen table 5, the values from the lowest sunspot number in the “preceding” and “after” formulas are remarkably similar, while the smoothed sunspot number is close to these values.

Table 5.: the month of the start of the cycle with the preceding 6 months (1/2 first month) divided by 6 and the month of the start with the following six months (½ last month) divided by 6.

Cycle number	Start cycle	Sunspot Number Centered month + 6 months preceding (½ first month) divided by 6		Sunspot Number Centered month + 6 months after (1/2 last month) divided by 6		Smoothed sunspot number at start cycle
	Date	Date	SSN	Date	SSN	SSN
19	1954/04	1954/06	3.88	1954/01	4.16	5.1
20	1964/10	1964/11	11.09	1964/05	11.36	14.3
21	1976/03	1976/07	18.36	1975/09	17.91	17.8
22	1986/09	1986/09	13.18	1986/03	13.91	13.5
23	1996/09	1996/10	10.45	1996/04	10.96	11.2
24	2008/12	2009/05	1.92	2008/12	1.98	2.2
	2019/11-12	2019/12	0.92	2019/06	0.89	

Lowest sunspot number with centered month + 6 months preceding:

Cycle 19: 2 months late
Cycle 20: 1 month late
Cycle 21: 4 months late
Cycle 22: exact
Cycle 23: 1 month late
Cycle 24: 5 months late
Cycle 25: exact to 5 months late or August-December 2019

Lowest sunspot number with centered month + 6 months after:
Cycle 19: 3 months early
Cycle 20: 5 months early
Cycle 21: 4 months early
Cycle 22: 6 months early
Cycle 23: 5 months early
Cycle 24: exact
Cycle 25: exact to 6 months early or June-December 2019

The overlapping period between the two methods for the start of Cycle 25 is August-December 2019

6.1 2K and 1K high resolution sunspot number from start date and in the 6 months preceding and after the start of each cycle

Because the 1K and 2K sunspot numbers are 2.5 to 7 times higher and therefore more accurate, we made the same calculations as the ISN to try to find the lowest smoothed sunspot number for 1K and 2K. The high resolution sunspot numbers give the same date for the lowest sunspot numbers as the ISN as presented in table 6.

Table 6 presents the same results as table 5, but this time using the 2K and 1K high resolution sunspot number.

Cycle number	Start cycle	Sunspot Number Centered month + 6 months preceding (½ first month) divided by 6		Sunspot Number Centered month + 6 months after (1/2 last month) divided by 6	
	Date	Date	2K	Date	2K
25	2019/11-12	2019/12	11.0	2019/06	11.3
		Date	1K	Date	1K
25	2019/11-12	2019/12	4.4	2019/06	4.4

Projection 2K sunspot number based upon a smoothed sunspot number of 11.4 SSN for December 2019

If we take 11.4 as the most likely smoothed sunspot number for the 2K method, we notice that December 2019 falls most in line with our prediction.
The following values are the same as our prediction on Researchgate https://www.researchgate.net/publication/341370351_The_Adjusted_Solar_Flux_the_Start_of_Solar_Cycle_25 in early May 2020. Because we had a relatively high sunspot number in April 2020 and sunspot values go in waves, we used a lower value for May 2020, a slightly stronger one for June 2020 and a stronger one for July 2020. The final smoothed 2K value, 11.8 SSN, was a bit higher than 11.4 SSN, but our prediction was right.
Predicted monthly mean sunspot number 2K
May 2020: 9 SN
June 2020: 12 SN
July 2020: 22 SN

Projection 1K sunspot number based upon a smoothed sunspot number of 4.6 SSN for December 2019

We made a similar prediction for the 1K high resolution sunspot number. The final 1K smoothed sunspot number was 4.8 SSN instead of 4.6 SSN predicted.
Predicted monthly mean sunspot number 1K
May 2020: 3 SN
June 2020: 6 SN
July 2020: 12 SN

Projection ISN sunspot number based upon a smoothed sunspot number of 1.9 SSN for December 2019

The ISN was more complicated because of the low values. However, we used the same direction like the 1K and 2K predictions. The final smoothed value was 1.8 SSN instead of 1.9 SSN.

Predicted monthly mean sunspot number ISN
May 2020: 2 SN
June 2020: 3 SN
July 2020: 8 SN

7.0 A marker for the start of a new sunspot Cycle

We found a fairly easy formula (Geryl and Alvestad, 2020), for the high values to converse flux numbers to sunspot numbers, and vice versa: the new formula works both ways and gives smaller differences than the older ones. But we should wonder about the differences between the proxies at the low values and why they differ so much. After studying multiple possibilities, it seems that a hidden formula can be found: a usable predictor for the start of a new sunspot cycle. To this end, one has to divide the smoothed fitted adjusted flux by the smoothed fitted monthly mean sunspot number as presented in figure 4 and table 7.

7.1 Formula start new sunspot Cycle from smoothed fitted values

Our research identified the following formula to calculate the start of the new sunspot Cycle from smoothed fitted values:
$((F10.7/SSNf * 100-100)/10)+100$

Where:
F10.7 = smoothed fitted monthly mean adjusted flux
SSNf = smoothed fitted monthly mean sunspot number

Figure 4 presents the difference between the smoothed fitted adjusted flux and the smoothed fitted sunspot number.

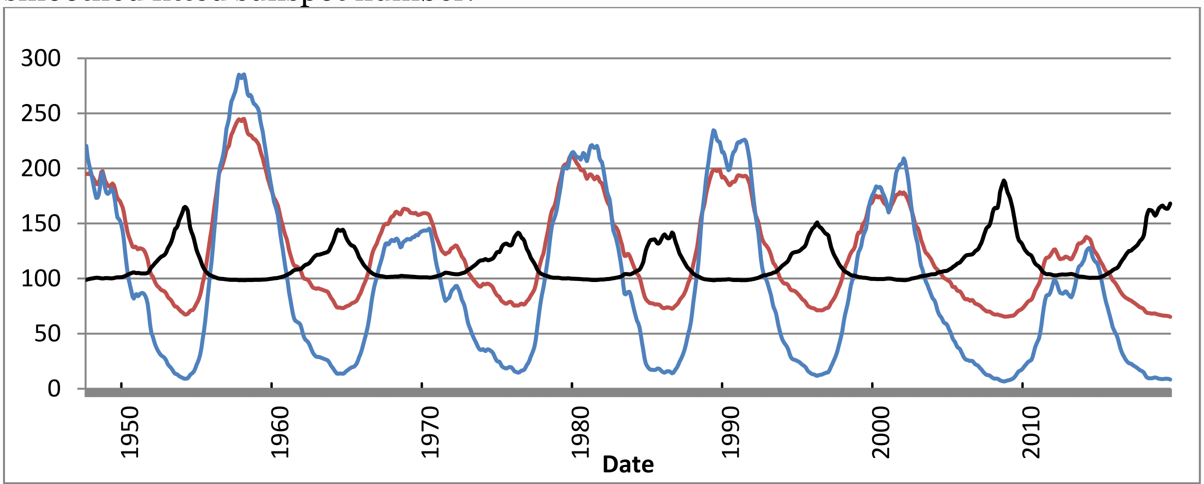

Figure 4. September 1947 – December 2019.
Black = strength between smoothed fitted adjusted flux divided by smoothed fitted sunspot number.
Red = fitted smoothed mean adjusted flux
Blue = fitted smoothed monthly mean sunspot number

Source:
S.I.D.C. Brussels International Sunspot Number.
World Data Center for Solar-Terrestrial Physics, Moscow using the 10.7cm radio flux values (sfu) from Ottawa and Penticton, B.C., Canada.
Solar Terrestrial Activity Report

Table 7 presents the strength in relation to the start of sunspot Cycles.

Cycle number	Start cycle	Strength smoothed fitted adjusted flux divided by smoothed fitted sunspot number	
	Date	Date	Strength
19	1954/04	1954/04	165.1
20	1964/10	1964/06	144.5
21	1976/03	1976/06	141.6
22	1986/09	1986/09	141.9
23	1996/08	1996/05	151.0
24	2008/12	2008/10	189.1
25	2019/11-12	2019/12	168.4

We can interpret the results as follows:
Cycle 19: exact prediction
Cycle 20: 4 months early
Cycle 21: 3 months late
Cycle 22: exact
Cycle 23: 3 months early
Cycle 24: 2 months early
Cycle 25: The highest point was in May 2019. This would yield a date at the latest in September 2019. This wasn't the case, so our formula needs to make a new high starting from November 2019.

Our empirical formula tries to find the time period for the maximum strength of the fitted smoothed solar radio flux to the fitted smoothed sunspot number. It shows a relation with the start of a new sunspot cycle, although it isn't a perfect formula, because plage areas with no sunspots visible contribute to bumps in the solar flux. Nevertheless, the formula was exact in Solar Cycles 19 and 22, 4 months early in Cycle 20, 3 months early in Cycle 23, 3 months late in Cycle 21, and 2 months early in Cycle 24. In case of Solar Cycle 25, our formula needs to form a new high in November 2019 – March 2020 (exact to 3 months late). This way we can make several theoretical possibilities for the months May-July 2020 as expressed in table 8.

Table 8. If the start from Cycle 25 falls in November-December 2019 as previously found, we have the following values:

Date	SSN	Adjusted flux	Strength smoothed fitted adjusted flux divided by smoothed fitted sunspot number		Smoothed SSN at start cycle
			Date	Strength	
2020/05	2	71.0	2019/11	167.9	2.1
2020/06	3	71.0	2019/12	168.4	1.9
2020/07	8	73.0	2020/01	166.6	2.3
2020/05	4	71.5	2019/11	167.7	2.2
2020/06	10	73.0	2019/12	167.0	2.4
2020/07	8	73.0	2020/01	163.8	3.0

In case number 1 the lowest smoothed ISN number falls in December 2019 with a smoothed SSN of 1.9, while in case number 2 it falls in November 2019 with a smoothed SSN of 2.2.
The final strength from the smoothed fitted adjusted flux divided by the smoothed fitted sunspot number was 168.4 in December 2019, the same as predicted, although the SSN and the adjusted flux were slightly different for the 3 months.

8.0 Relating the 'Terminator' to the start of Solar Cycle 25

Our findings can also be used to calculate the 'Terminator', a very short time period, less than a solar rotation, in which both hemispheres show remarkable activity. McIntosh et al (2019) calculated it for late 2019 to early 2020. A follow up article from Leamon et al (2020) placed it in May 2020. However, they made a basic error by only crudely relating it to the start of a new cycle. This can be easily done with our findings. If we use our formula for the forward looking smoothed sunspot number, we can compare the lowest point with the start of the terminator. In table 9 we present the first precursor: the month of the start of the cycle with the preceding 6 months (1/2 first month) divided by 6, and in table 10 we present the second precursor: the month of the start with the following six months (½ last month) divided by 6:

Table 9. Months in which the terminator appeared (McIntosh et al, 2019) in relation to our first precursor for the start of a new sunspot cycle, followed by the number of months till the terminator went active.

Cycle number	**Terminator Date**	**Sunspot Number Centered month + 6 months preceding (½ first month) divided by 6 Date**	**Months to 'Terminator' Months**
13	1891/03	1890/04	11
14	1904/08	1901/12	32
15	1915/01	1913/09	16
16	1925/06	1923/08	22
17	1935/08	1934/01	19
18	1945/08	1944/07	13
19	1955/08	1954/06	14
20	1966/06	1964/11	19
21	1978/01	1976/07	18
22	1988/06	1986/09	21
23	1997/08	1996/10	10
24	2011/02	2009/05	21
25		2019/12	10-22*

*We exclude the value from cycle 14 because this was a weak cycle, while we expect cycle 25 to be quite strong.

Our first precursor had its lowest value in December 2019. The shortest time in which a terminator appeared was 10 months after the lowest precursor value. The longest timer period was 22 months. So apparently this gives us a time period between October 2020 and October 2021, with a mean of April 2021 for the next terminator:

2019/12 + 10 = 2020/10
2019/12 + 22 = 2021/10
Mean = 2021/04

Table 10. Months in which the terminator appeared (McIntosh et al, 2019) in relation to our second precursor for the start of a new sunspot cycle, followed by the number of months till the terminator went active.

Cycle number	**Terminator** **Date**	**Sunspot Number Centered month + 6 months preceding (½ first month) divided by 6** **Date**	**Months to 'Terminator'** **Months**
13	1891/03	1889/10	17
14	1904/08	1901/07	37
15	1915/01	1913/03	22
16	1925/06	1923/02	28
17	1935/08	1933/07	25
18	1945/08	1944/01	19
19	1955/08	1954/01	19
20	1966/06	1964/05	25
21	1978/01	1975/09	28
22	1988/06	1986/03	27
23	1997/08	1996/04	16
24	2011/02	2008/12	26
25		2019/06	16-28*

*We exclude the value from cycle 14 because this was a weak cycle, while we expect cycle 25 to be quite strong.

Our second precursor had its lowest value in June 2019. The shortest time in which a terminator appeared was 16 months after the lowest precursor value. The longest timer period was 28 months. So apparently this gives us a time period between October 2020 and October 2021, with a mean of April 2021 for the next terminator:

2019/06 + 16= 2020/10
2019/06+ 28 = 2021/10
Mean = 2021/04

The question is now if this allows us to determine the terminator more accurately. It depends from the strength of the cycle and several other factors which we are still investigating. One way is the time between the first terminator in 1891/03 till 2011/02: it amounts to 1,439 months. In the same manner we find a difference from 1,556 months between the first precursor starting in 1890/04 till 2019/12 and the same amount of 1,556 months between the second precursor starting in 1889/10 till 2019/06. The difference between the terminator and the first or second precursor equals 117 (1,556-1,439).
If we add 117 months to 2011/02, the result leads to 2020/11. Thus November 2020 becomes a first but **minor** candidate for the "Terminator", while the mean calculation falls in April 2021.

8.1 Predictions for the start of sunspot cycle 25

Herewith follows a list from published papers for the start of Solar Cycle 25.
David Hathaway and co-author Lisa Upton predict a start for Cycle 25 in 2020-2021.
In August 2018 they published "An Updated Solar Cycle 25 Prediction with AFT: The Modern Minimum". Key Points of this update were:

• Cycle 25 will be slightly weaker than Cycle 24, making it the weakest cycle on record in the last hundred years.
• Weak cycles are preceded by long extended minima – we may not reach the Cycle 24/25 minimum until 2021.
They expect that '*the Cycle 24-25 minimum will include extended periods of spotless days throughout 2020 and into 2021.*'
Many researchers follow a time line in 2020-2021 for the start of sunspot cycle 25:

- Pessnell & Schatten (2018) think 2020 - 2021.
- F.Y.Li et al (2018) think October 2020.
- The latest Solar Cycle Prediction Panel thinks April 2020.

9.0 X flare potential and start 'Terminator'

Regular X-ray data became first available in 1976 and therefore our research has to stay limited from that time period till now. Table 11 lists the most significant solar flares (since 1976) after the start of the 'Terminator', from which some had dramatic effects on HF communications and other systems. As can be seen an x15.0 happened 6 months after the terminator in 1978 and one with the same strength 9 months after the terminator in 1988. The x9.4 happened just 3 months after the terminator from cycle 23. The start of the terminator from Solar Cycle 24 delivered an x2.2 followed six months later by an x6.9 event. Because we think that cycle 25 will be more powerful than cycle 24, an x-flare in excess of >x10.0 could happen in 2021.

Table 11. Months in which a significant solar flare happened within 9 months of the Terminator

Cycle number	Terminator Date	Date	X-ray class
21	1978/01	1978/07/11	x15.0
22	1988/06	1989/03/06	x15.0
23	1997/08	1997/11/06	x9.4
24	2011/02	2011/02/15	x2.2
		2011/08/09	x6.9
25	2021/04-06	2021/06-12	>x10.0?

Source: Solar X-ray flares from the GOES satellite 1975 to present

10.0 Discussion and Conclusion

With the findings from this paper, we can find a time frame for a reversal. The lowest adjusted 10.7 cm solar flux values give an indication for the starting point of a new Solar Cycle. A more accurate date can be found by using the smoothed adjusted solar flux values in combination with the smoothed sunspot numbers. However, this point can only be calculated 7-10 months after the start of a new cycle. In contrast, the lowest adjusted flux was reached in October 2019 and points to a start of Cycle 25 between August 2019 and January 2020. This raised the question if Cycle 25 is late, exact or early in relation to the adjusted flux. The centered formulas from sections 4.0 and 6.0 narrow it further to the period August-December 2019. Furthermore, the huge discrepancies in August 2019 and February 2020 between the fitted and measured sunspot number point towards the period November to December 2019 as the most likely period for the start of Solar Cycle 25. This is confirmed by the smoothed formula from the adjusted flux from section 7.0. In addition, if we project the 2K smoothed sunspot number in the future, we find December 2019 as the most likely month for the start of Solar Cycle 25.

On December 9, 2019 The Solar Cycle Prediction Panel made its new prediction for the onset of Solar Cycle 25: April 2020. This in contrast with our findings which place it 4-5 months earlier, more specific in the period November to December 2019 and especially December 2019.

Establishing the start of a Solar Cycle is of primary concern for calculating the time frame of the 'Terminator'. Mausumi Dikpati et al (2019) think the terminator will happen sometime in 2020. There is no date given for the start of Solar Cycle 25. McIntosh et al (2019) stated that the current minimum will be no later than mid-late 2019, while the "Terminator" falls in late 2019 to early 2020. The mean from our calculations falls more than a year after their attempt and shows they made an essential error by not incorporating the exact start in their work. Leamon et al (2020) shifted the start to May 2020 but again didn't use the right start of Solar Cycle 25. Our earliest, but not most likely, forecast for the 'Terminator' falls just after their maximum possible date (November vs September 2020) while our mean calculation for the **right** date falls in April 2021.

An important question follows from this: will their complicated mathematics and extensive analysis fail because they couldn't establish the right low points between cycles? And in contrast, will our effort to find the start of a new Solar Cycle while incorporating this in relation to the terminator succeed? Without any doubt this shows that the transition between cycles is far more important than currently accepted.

Another factor to be considered is a large X-ray solar flare (>x10.0), which could give a serious blow to the earth's weakened magnetic field. This could happen somewhere between June and December 2021.

Data Availability Statement

The sunspot numbers used in this paper are available at SILSO, World Data Center - Sunspot Number and Long-term Solar Observations, Royal Observatory of Belgium, on-line Sunspot Number catalogue: http://www.sidc.be/silso/datafiles 'year(s)-of-data 1885-2020'. The high resolution sunspot numbers are available at http://www.solen.info/solar . Natural Resources Canada provides F10.7 solar flux data online (**http://www.spaceweather.ca/solarflux/sx-en.php**). The solar flux values from Penticton are measured automatically. Faults due to solar flares and other disturbances are not corrected. Therefore, we use the values from the http://www.wdcb.ru/stp/data/solar.act/flux10.7/ World Data Center for Solar-Terrestrial Physics, Moscow and also these from "Solar Terrestrial Activity Report" or STAR since January 2012 http://www.solen.info/solar/

The solar X-ray flare data are available at NOAA https://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-features/solar-flares/x-rays/goes/

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Table 12. High resolution sunspots give a better value and seem to follow the ISN, but the 2K high resolution sunspot calculations point to June 2019 **as an early signal** for the start of Solar Cycle 25:

Date	**13 month smoothed values High resolution 2K STAR**	**13 month smoothed values High resolution 1K STAR**	**13 month smoothed values ISN**
September 2018	15.9	9.3	6.5
October 2018	16.1	9.5	6.8
November 2018	15.6	9.4	6.7
December 2018	14.9	8.9	6.0
January 2019	14.5	8.5	5.4
February 2019	13.9	8.1	5.0
March 2019	13.1	7.6	4.6
April 2019	12.7	7.2	4.3
May 2019	12.4	6.9	3.9
June 2019	12.4	6.7	3.7
July 2019	12.8	6.6	3.5
August 2019	13.1	6.6	3.4
September 2019	12.6	6.1	3.1
October 2019	12.3	5.6	2.6
November 2019	12.0	5.1	2.0
December 2019	11.8	4.8	1.8
January 2020	12.2	5.2	2.2
February 2020	13.4	5.9	2.8

Links to excel files

Table 1
Excel: Cycle 25 / Go to SIDC smoothed
Adjusted flux WDC: Column D
Adjusted flux STAR; Colum D from 2012/01
Observed flux WDC: Column R
Observed flux STAR: Column R from 2018/04

Table 2
Excel: Cycle 25 / Go to SIDC smoothed
Column: F

Table 3
Excel: Cycle 25 / Go to SIDC 6 months B & A
Column: K
Excel: Solar Cycle 25 / Go to SOLEN 6 months B & A
2K: Column J
1K: Column U

Table 4
Excel: Solar Flux 1947till2018 / Go to TABLE 8
Column H

Table 5
Excel: Cycle 25 / Go to SIDC 6 months B&A
Columns F and G

Table 6
Excel: Cycle 25 / Go to SOLEN 6 months B&A
Columns E and F

Table 7
Excel: Solar Flux 1947till2018 / Go to TABLE 6
Columns L M N
Table 8
Excel: Solar Flux 1947till2018 / Go to TABLE 6

Columns L M N

Table 9
Excel: Cycle 25 / Go to SIDC 6 months B&A
Columns F and U

Table 10
Excel: Cycle 25 / Go to SOLEN 6 months B&A
Columns G and V

Table 12
Excel: Cycle 25 / Go to SIDC smoothed
Column G
Go to Solen smoothed
Column G for 2K smoothed
Column L for 1K smoothed

Figure 1
Excel: Cycle 25 / Go to SIDC smoothed
Column R, S and T

Figure 2
Excel: Cycle 25 / Go to SIDC smoothed
Figure 2 / Columns E till G

Figure 3
Excel: Cycle 25 / Go to SIDC 6 months B & A
Figure 3 / Columns K till M

Figure 4
Excel: Solar Flux 1947till2018 / Go to Figure 5

Until now the lowest adjusted flux was 66.5 for January 1954 (note: values corrected for flaring and snow from the Data World Data Center for Solar-Terrestrial Physics, Moscow. They use the original CORRECTED data from Ottawa: http://www.wdcb.ru/stp/data/solar.act/flux10.7/
However, there were only 22 recorded days in January 1954, so this value has to be eliminated.
The second lowest value is 67.0 from December 2008. This is the same value like the one from October 2019. Therefore our claim that this is a very low value to be considered for the start of a new Cycle.

1954 ADJUSTED DAILY SOLAR FLUX 1954
Ottawa 2800 MHz Series C (Multiplied by Ten) 1700 UT

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	---	685	694	692	---	667	704	715	693	742	692	746
2	674	673	686	635	697	683	665	715	693	---	695	737
3	---	657	689	---	690	690	692	705	726	665	616	714
4	659	688	687	---	704	690	702	697	---	735	666	---
5	662	676	685	676	703	705	703	706	703	759	682	728
6	631	---	---	677	688	688	707	728	705	762	---	693
7	663	---	---	694	699	696	---	726	676	749	---	705
8	658	665	695	718	---	695	697	722	694	754	729	699
9	---	---	692	700	---	714	697	732	718	744	762	714
10	---	676	695	707	703	712	---	749	705	---	789	690
11	699	674	693	686	700	702	---	726	---	---	820	---
12	681	---	694	715	695	685	703	728	713	724	776	715
13	650	---	---	717	695	686	708	713	680	742	---	707
14	663	---	---	697	695	706	706	---	708	751	---	726
15	682	682	827	712	680	701	704	723	700	735	747	779
16	---	666	795	---	---	709	690	718	699	---	727	788
17	647	---	786	703	699	695	703	699	712	749	717	756
18	666	670	767	698	694	703	688	704	---	741	714	---
19	681	656	773	694	---	695	694	688	---	728	704	761
20	654	---	709	681	678	666	696	702	725	738	---	747
21	688	---	721	710	692	673	678	---	703	708	675	733
22	661	656	704	699	697	681	---	716	703	710	669	729
23	---	680	684	678	679	698	700	737	720	---	699	741
24	---	667	695	685	697	699	---	737	712	706	705	746
25	650	684	692	691	703	699	691	733	---	720	689	---
26	666	691	644	691	700	691	710	731	706	720	670	724
27	656	---	---	687	709	651	716	710	718	693	---	706
28	670	690	687	675	678	719	703	---	718	708	---	---
29	657		---	680	---	714	710	694	733	687	673	712
30	---		---	684	694	705	714	700	748	---	708	740
31	---		674		705		---	691		694		768
Mean	665	675	711	692	695	694	700	716	709	727	710	731

1954 Yearly Mean = 702