International Journal of Innovation in Science and Mathematics
Volume 12, Issue 5, ISSN (Online): 2347–9051

Comparison of Solar Cycle 24 with 3 Previous Cycles in respect of Sunspot Number Data

Debojyoti Halder
Department of Physics, Rishi Bankim Chandra Evening College, Naihati, West Bengal, India.
Corresponding author email id: debojyoti_halder@rbcec.in

Date of publication (dd/mm/yyyy): 03/10/2024

***Abstract* – Solar cycle 24 is the most recently completed solar cycle, the 24th since 1755, when extensive recording of solar sunspot activity began. It began in December 2008 and ended in December 2019. Activity was minimal until early 2010. It reached its maximum in April 2014 with a 23 months smoothed sunspot number of 81.8. This maximum value was substantially lower than previous three solar cycles. In this paper, a thorough analysis of all the sunspots appeared during the complete period has been done carefully and the daily sunspot numbers against their appearing dates for each solar cycle have been plotted. It appears that the sunspot activity has been on the lower side for solar cycle 24 when compared to the three previous solar cycles - cycle 21,22 and 23.**

***Keywords* – Solar Cycle 21, Solar Cycle 22, Solar Cycle 23, Solar Cycle 24, Sunspot Number.**

I. INTRODUCTION

Solar activity rises and falls with an 11-year cycle, which is called the Solar Cycle, that affects us in many ways. Increased solar activity includes increase in the number of solar flares and coronal mass ejections (CMEs) which in turn affects sensitive instruments in space by energetic particles accelerated in these events. Every part of the solar activity is strongly modulated by the solar magnetic cycle [1]. Solar flares are intense localized eruption of electromagnetic radiation from the Sun's atmosphere. Flares occur in active regions and are mostly accompanied by CMEs, solar particle events, and other solar phenomena. The occurrence of solar flares varies with the 11-year solar cycle. Solar cycle 24 is the most recently completed solar cycle. It began in the end of 2008 or beginning of 2009 with a minimum smoothed sunspot number of 2.2, and ended in December, 2019 [2]. Solar activity for this solar cycle was minimal until early 2010. It reached its maximum in April 2014. This maximum value was substantially lower than previous three solar cycles, down to a level which had not been seen since Dalton minimum (1790-1830) [3]. Here, we have done an analysis on the daily sunspot numbers data for all the calendar dates in each year of the solar cycle 24 and compared it with the same data for the three previous solar cycles namely solar cycle 21 (March 1976 to September 1986), solar cycle 22 (September 1986 to August 1996) and solar cycle 23 (August 1996 to December 2008). The solar cycle 24 has not generated sunspots and solar flare events in the expected manner.

II. SUNSPOT NUMBER ANALYSIS

A thorough analysis of all the sunspots appeared during the complete period has been done carefully and the daily sunspot numbers against their appearing dates for each solar cycle have been plotted.

2.1. *Solar Cycle 21*

The solar cycle 21 began from March 1976 and ended in September 1986, therefore lasted for 10.5 years. The maximum smoothed sunspot number observed during the solar cycle was 232.9, in December 1979, and the starting minimum was 17.8 [4]. During the transit from solar cycle 21 to 22, there were a total of 273 days with no sunspots [5]. In Figure 1, daily sunspots numbers with the whole duration of the solar cycles 21 have been plo-

-tted. Linear trendline equation also has been drawn in red dotted line.

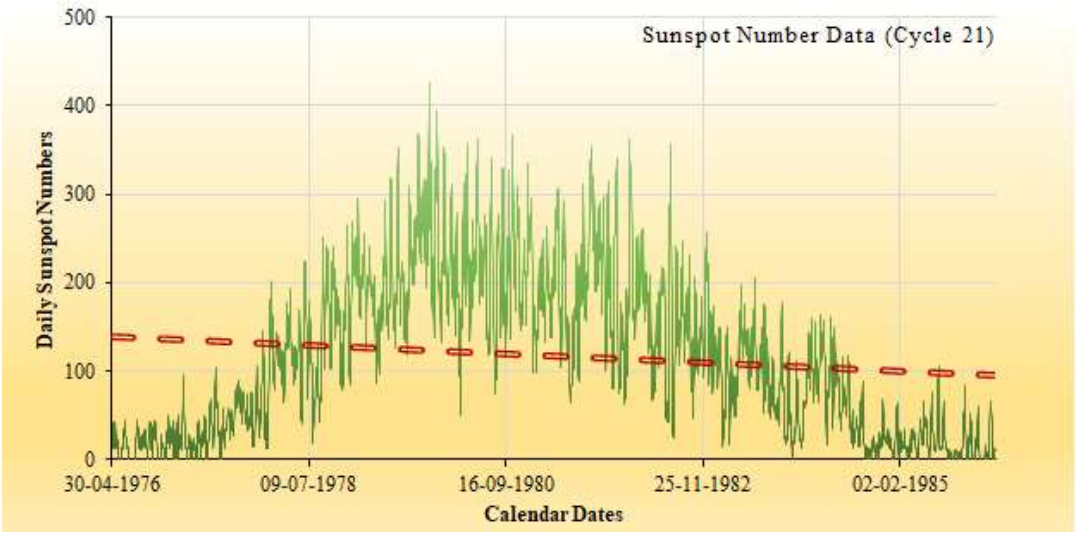

Fig. 1. Daily Sunspot Numbers plotted with Calendar dates for the duration of solar cycle 21.

2.2. *Solar Cycle 22*

The solar cycle 22 lasted for 9.9 years, beginning in September 1986 and ending in August 1996. The maximum smoothed sunspot number observed during the solar cycle was 212.5 in November 1989 and the starting minimum was 13.5 [4]. During the minimum transit from solar cycle 22 to 23, there were a total of 309 days with no sunspots [5]. In Figure 2, daily sunspots numbers with the whole duration of the solar cycles 22 have been plotted. Linear trendline equation also has been drawn in red dotted line.

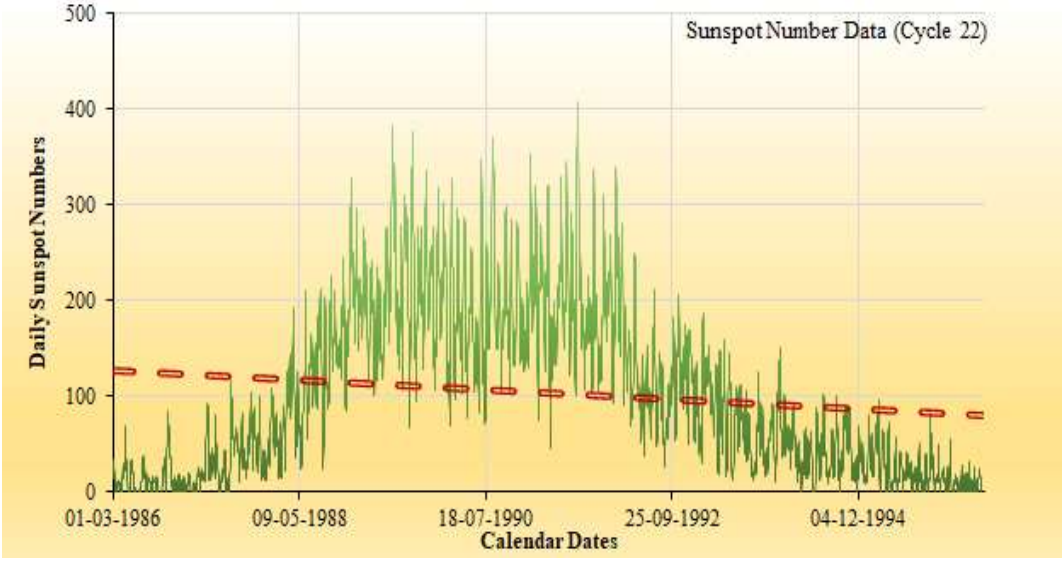

Fig. 2. Daily Sunspot Numbers plotted with Calendar dates for the duration of solar cycle 22.

2.3. *Solar Cycle 23*

The solar cycle 23 lasted for 12.3 years which began in August 1996 and ended in December 2008. The maximum smoothed sunspot number observed during the solar cycle was 180.3 in November 2001 and the starting minimum was 11.2 [4]. During the transit from solar cycle 23 to 24, there were a total of 817 days with

no sunspots [5]. When compared to the last two solar cycles, the solar activity of this cycle 23 was fairly low. In Figure 3, daily sunspots numbers with the whole duration of the solar cycles 23 have been plotted. Linear trendline equation also has been drawn in red dotted line.

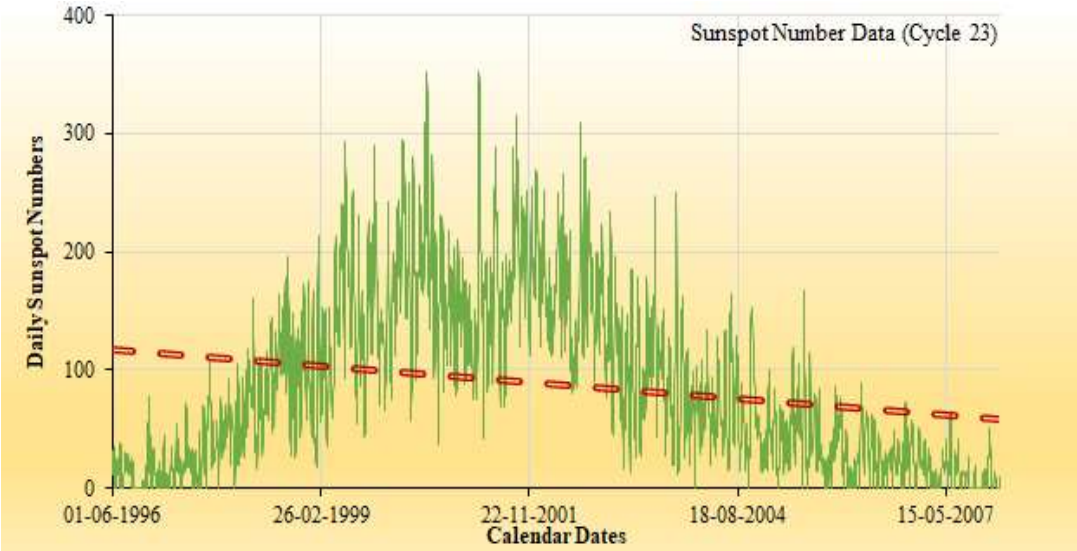

Fig. 3. Daily Sunspot Numbers plotted with Calendar dates for the duration of solar cycle 23.

2.4. *Solar Cycle 24*

The solar cycle 24 began in December 2008 with a minimum smoothed sunspot number of 2.2 and ended in December 2019. Solar activity was minimal until early 2010. It reached its maximum in April 2014 with a 23 months smoothed sunspot number of 81.8 [6]. This maximum value was substantially lower than previous three solar cycles. In Figure 4, daily sunspots numbers with the whole duration of the solar cycles 24 have been plotted. Linear trendline equation also has been drawn in red dotted line.

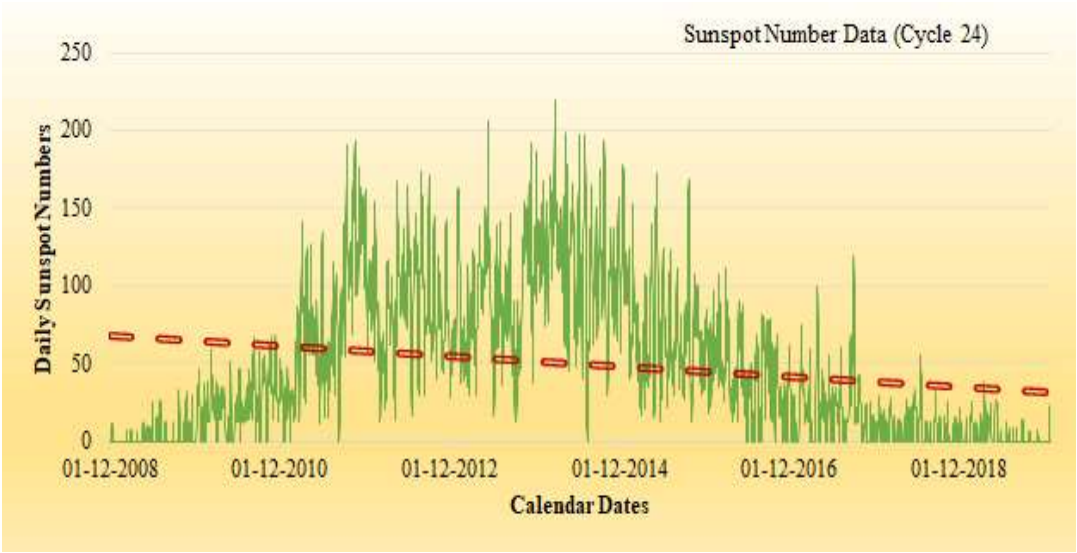

Fig. 4. Daily Sunspot Numbers plotted with Calendar dates for the duration of solar cycle 24.

The figures show that while for the solar cycles 21 and 22 the peak sunspot number reaching above 400, for cycle 23 the number is around 350 and for cycle 24, peak sunspot number is around 200. So, the decrease in peak sunspot number from cycle 21 to 24 evidently leads us to a low solar activity day.

III. Trend Line Equations for the Solar Cycles

Here the linear trend line equations for the four solar cycles have been compared with their respective R-squared values. The linear trend line equations are in the form $y = mx + c$, where m stands for *gradient* and c is the height at which the line crosses the y-axis known as the *y-intercept*. The equations are as follows.

Trend line equation for Cycle 21: $y = -0.0122x + 480.1$

Trend line equation for Cycle 22: $y = -0.0127x + 525.52$

Trend line equation for Cycle 23: $y = -0.0139x + 605.36$

Trend line equation for Cycle 24: $y = -0.009x + 425.06$

Table 1. Comparison of Slopes, Intercepts and R-Squared Values of SSN Plots for all the Four Solar Cycles.

Cycle No.	Slope (m)	Intercept (c)	R-squared
Cycle 21	- 0.0122	+ 480.1	+ 0.0194
Cycle 22	- 0.0127	+ 525.52	+ 0.0247
Cycle 23	- 0.0139	+ 605.36	+ 0.0563
Cycle 24	- 0.009	+ 425.06	+ 0.0488

IV. Conclusion

It is clearly evident from the figures that, while for the solar cycles 21 and 22 the peak sunspot number reaching above 400, for cycle 23 the number is around 350 and for cycle 24, peak sunspot number is around 200. So, the decrease in peak sunspot number from cycle 21 to 24 evidently leads us to a low solar activity day. Also, the table shows that, the previous three solar cycles 21 to 23 have been on the same trend but for the solar cycle 24 the values of slope (m), intercept (c) and R-squared values have different trend. The values of slopes for the previous three cycles were increasing (with negative values) but for solar cycle 24 slope gets a higher value than the previous three cycles i.e. the curve gets flatter.

V. Data Sources

1. Sunspot Number | SIDC (https://www.sidc.be)
2. SpaceWeather.com: Spotless Days: The Sun Plunges into the Deepest Solar Minimum in a Century
3. Space Weather Archive | SpaceWeatherLive.com.

References

[1] R.P. Kane, Some Implications Using the Group Sunspot Number Reconstruction, Solar Physics 205(2), 2002, 383-401.
[2] D. Halder, Regression Analysis of Sunspot Numbers for the Solar Cycle 24 in Comparison to Previous Three Cycles, Journal of Advances in Physics, 4(2), 2014, 477-483.
[3] Joanna D. Haigh, The Sun and the Earth's Climate, Living Reviews in Solar Physics, 4, 2007, 2.
[4] Sunspot Number | SIDC (https://www.sidc.be)
[5] SpaceWeather.com: Spotless Days: The Sun Plunges into the Deepest Solar Minimum in a Century
[6] Space Weather Archive | SpaceWeatherLive.com

Author's Profile

Debojyoti Halder, Department of Physics, Rishi Bankim Chandra Evening College, Naihati, West Bengal, India.