

# Analysis of Variations in Sunspot Characteristic Patterns during Solar Cycle 24

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**Abstract:** *Solar Cycle 24 exhibited comparatively low solar activity, making it an important period for studying changes in sunspot behavior. This study analyzes the variations in characteristic patterns of sunspots during Solar Cycle 24, focusing on parameters such as sunspot number, size, distribution, and temporal evolution. Observational data collected over the duration of the cycle were examined to identify trends in sunspot emergence and decay. The analysis reveals noticeable fluctuations in sunspot activity corresponding to different phases of the solar cycle, with peak activity occurring near solar maximum and reduced activity during solar minimum. Additionally, variations in hemispheric distribution and sunspot group complexity were observed, reflecting changes in the Sun's magnetic field dynamics. The results contribute to a better understanding of solar magnetic activity and highlight the distinct features of Solar Cycle 24 compared to previous cycles. This study supports ongoing efforts to improve solar cycle prediction models and enhances knowledge of solar variability and its potential impact on space weather.*

**Keywords:** Sunspots, Solar Cycle 24, Solar Activity, Sunspot Patterns, Solar Magnetic Field, Sunspot Variability, Space Weather

## I. INTRODUCTION

Sunspots are temporary dark regions on the solar surface associated with intense magnetic activity. The approximately 11-year solar cycle governs their periodic variation, influencing solar radiation, solar wind, and geomagnetic activity. Solar Cycle is fundamental in understanding solar-terrestrial interactions. Solar Cycle 24 began after an unusually deep and prolonged minimum between 2007–2009, which was the longest in nearly a century. Unlike its predecessors, SC24 exhibited reduced activity levels, making it a subject of significant scientific interest.

The solar cycle, or solar activity cycle, is an approximately 11-year periodic change in the Sun's magnetic activity, visible through variations in sunspot numbers and solar radiation. It affects space weather, satellite operations, and Earth's upper atmosphere, making it vital for astronomy and climate science. The cycle is driven by the Sun's magnetic field, which undergoes a polarity reversal about every 11 years. Convection and rotation within the solar interior twist and tangle magnetic field lines, creating sunspots where field lines emerge. After each cycle, the magnetic poles swap, producing a 22-year magnetic period when polarity is considered. During solar maximum, sunspots, flares, and coronal mass ejections become frequent, intensifying auroras and sometimes disrupting communications and power grids. At solar minimum, the Sun's activity quiets, and the heliosphere's shielding effect against cosmic rays weakens, increasing cosmic radiation near Earth. Solar cycles are monitored using sunspot numbers and indices such as the 10.7 cm radio flux.

### 1.1 Data used

The sunspot number has been taken from the link: [Sunspot Number SIDC](#). and solar wind information has been taken from: [OMNI Web Data Explorer](#) The analysis of sunspot characteristic patterns during Solar Cycle 24 (~2008–2019) is



primarily based on internationally recognized solar datasets we have taken data in SILSO neutron monitor and make the graph sunspot number daily, monthly, yearly and define the problem.

**1.2 Result and Discussion**

Figure: 1 this is a time-series line graph showing monthly measurements of sunspot number over time. X-axis (horizontal): Years from 2008 to 2019 Y-axis (vertical): Sunspot number (a measure of solar activity) Data source concept: Solar Influences Data Analysis Center (SILSO) The graph define changes in solar activity across a solar cycle (around 11 years, known as the solar cycle). Sunspot numbers start low around 2008–2009 (solar minimum), rise to a peak around 2013–2014 (solar maximum), then steadily decline again toward 2019 (next minimum).

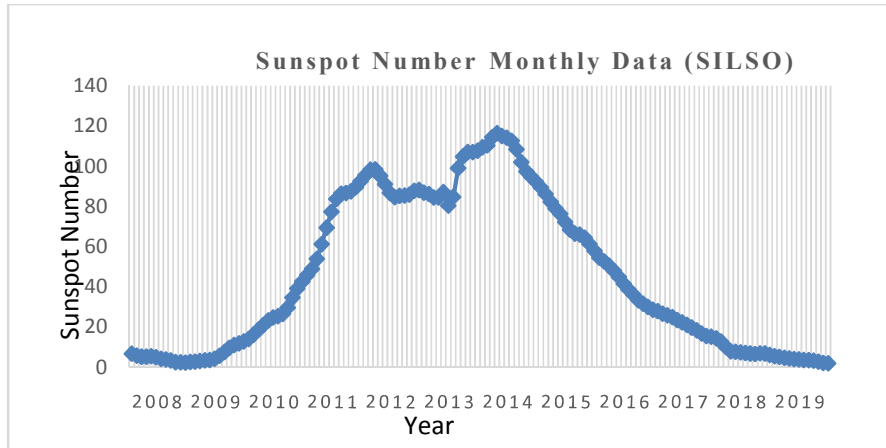


Figure:1 The Monthly Sunspot Number 2008 To 2019 (SILSO)

Figure: 2 Show yearly time-series line graph of sunspot number based on data from Solar Influences Data Analysis Center. X-axis: Years (2008–2019) Y-axis: Average sunspot number per year. Each point represents the annual average of solar activity. Very low activity in 2008–2009 (solar minimum) Rapid increase from 2010 to 2011 Peak around 2014 (~80 sunspots), marking the solar maximum Gradual decline from 2015 to 2019, returning toward another minimum.

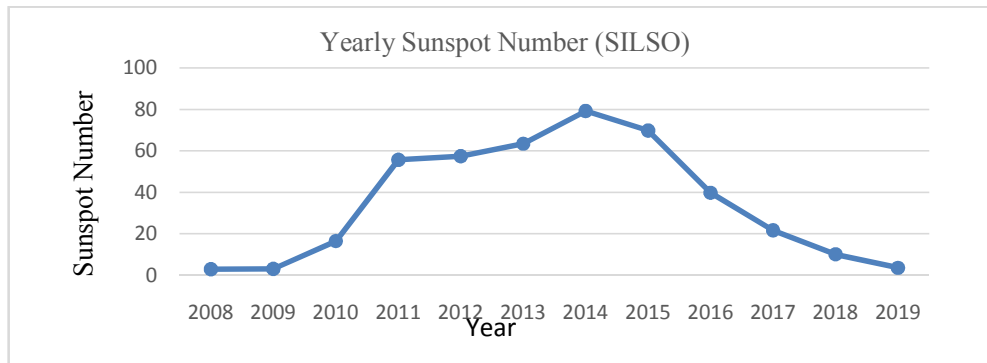


Figure: 2 the Yearly Sunspot Number 2008 to 2019 (SILSO)



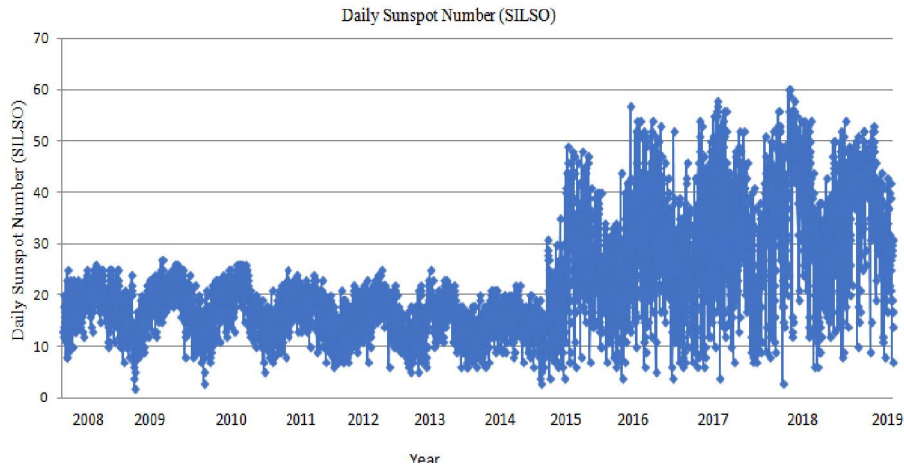


Figure: 3 show the value of daily sunspot number of 11 year

Figure: 3 show the daily sunspot number (SILSO) from about 2008 to 2019. Here's how to interpret what you're seeing: Sunspot activity follows an ~11-year cycle. Around 2008-2009, the values are relatively low this corresponds to a solar minimum. Activity gradually increases afterward, peaking roughly in the mid-2010s the solar maximum phase. After the peak (around 2014-2015), activity becomes more variable but generally trends downward again toward the next minimum. In low-activity years (2008-2010), values stay mostly between ~5-25. During higher activity (2015-2018), the spread is much wider (from near 0 up to ~60). This is expected more active suns produce more fluctuations and occasional bursts.

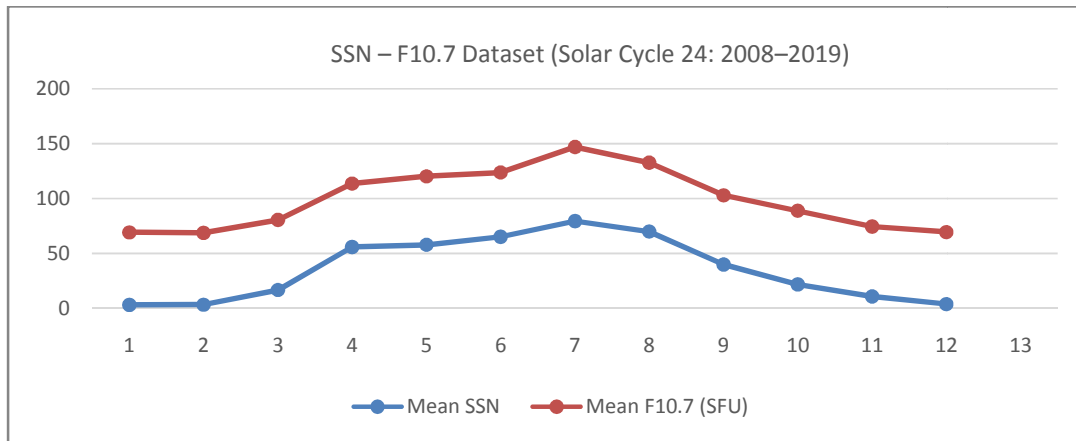
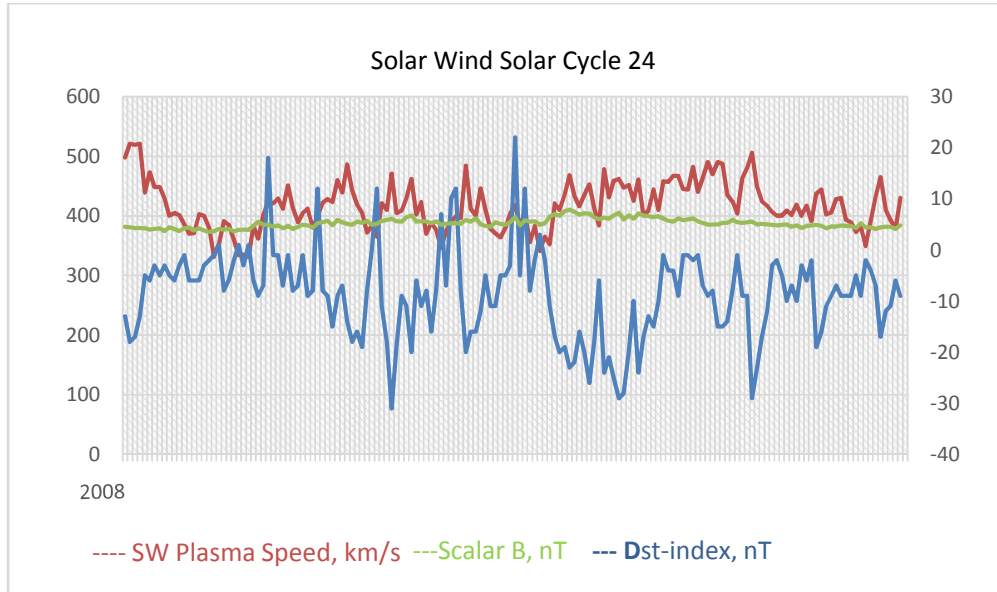


Figure: 4 SSN - F10.7 Dataset (Solar Cycle 24: 2008-2019)

Figure: 4 Represents the monthly variation of Mean Sunspot Number (SSN) and Mean F10.7 Solar Flux (SFU) over a typical solar activity cycle pattern (likely averaged behavior of Solar Cycle 24). Both SSN and F10.7 show a similar trend, rising to a peak and then declining. This again confirms a strong positive correlation between SSN and F10.7. Early Months (Jan-Mar) SSN is very low (~2-15) F10.7 remains relatively steady (~68-80 SFU). The monthly variation of SSN and F10.7 demonstrates a consistent solar cycle pattern characterized by a rapid phase, a well-defined maximum around mid-year, and a gradual decline. The strong agreement between the two parameters confirms their positive correlation, while the smoother variation of F10.7 highlights its reliability as a stable indicator of solar activity.





**Figure: 5** Show the solar wind (Solar cycle 24 2008-2019)

Figure:5 This graph titled “Solar Wind Solar Cycle 24” represents the variation of key space weather parameters from 2008 to 2019, covering Solar Cycle 24. It is a multi-parameter time series graph showing how solar wind conditions and geomagnetic activity change over time.

**The Graph Shows:**

**Solar Wind Plasma Speed (Red):**

Speed of charged particles emitted by the Sun. Higher values indicate faster Solar Wind Streams (SWS) or CMEs.

**Scalar B (Green):**

Magnitude of the interplanetary magnetic field (IMF) . It controls how strongly the solar wind couples with Earth’s magnetosphere.

**Dst Index (Blue):**

Measures geomagnetic storm intensity:

Near 0 → quiet conditions

Negative values → geomagnetic storms

More negative → stronger storm

The graph shows continuous fluctuations in solar wind (SW) and IMF over Solar Cycle 24. Sharp negative dips in Dst index indicate geomagnetic storms. These disturbances often occur when:

Solar wind speed (SWS) increases

interplanetary magnetic field (IMF) becomes stronger or more variable

**Comparison with Previous Cycles**

S.N.	Parameter	SC- 21-23	SC-24
1	Peak Sunspot Number	High (~150 –200)	Low (~82)
2	Rise Time	Faster	Slower



S.N.	Parameter	SC- 21-23	SC-24
3	Magnetic Activity	Strong	Weak
4	Sunspot Groups	Numerous large groups	Fewer large groups
5	Cycle Strength	Strong	Weak

This table is a comparison of solar activity characteristics between strong earlier solar cycles (21–23) and the weaker Solar Cycle 24.

## II. CONCLUSION

**Figures 1 and 2:** This graph illustrates Solar Cycle 24, depicting the characteristic behavior of solar activity—visually represented in the figures—wherein the solar cycle followed the pattern: Minimum → Rise → Maximum → Decline → Minimum. Figure 2: By the years 2018–2019, the values drop once again to very low levels (~2–10), signaling the conclusion of this cycle.

**Figure:3** Diagram clearly illustrates the time-based variations in daily sunspot activity observed during Solar Cycle 24, revealing the following changes:

Around the years 2008–2009, a state of quiet 'solar minimum' prevailed; this was followed by increasing activity and intense fluctuations during the active phase, reflecting the overall dynamic behavior of the Sun's magnetic activity.

**Figure:4** This diagram clearly illustrates that the solar radio flux (F10.7) closely follows the variations in sunspot numbers. Both parameters attain their maximum values during the Solar Maximum phase and gradually decrease afterward. The graph therefore demonstrates that the F10.7 index is an effective and reliable indicator of solar activity during Solar Cycle 24.

**Figure: 5** This diagram clearly establishes that during SC 24 (Solar Cycle 24), variations in solar wind speed (SWS) and the Interplanetary Magnetic Field (IMF) significantly impact the Dst index. Periods of heightened solar activity are associated with more intense geomagnetic disturbances; this confirms that (SWP)solar wind parameters play a crucial role in governing Earth's space weather environment.

In this research, we observed that Solar Cycle 24 was the least active compared to Solar Cycles 21 through 23. During Solar Cycle 24, sunspot activity was at its lowest in 2008–2009 and reached its peak in 2013–2014. Our research is not yet complete; we will continue our investigations and share any further findings we obtain.

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