ANALYTICAL STUDY OF SOLAR ACTIVITY PARAMETERS FOR RECENT SOLAR CYCLE 23, 24 AND 25.

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ABSTRACT
One of the energetic environments under study in contemporary astrophysics is the solar environment. The term "solar activity" refers to physical phenomena that take place in the sun's outer atmosphere over the course of solar cycles 23, 24 and 25. The solar cycle, also referred to as the solar magnetic cycle, is an almost change in the Sun's activity that lasts 11 years. The fundamental parameters that govern solar activity are sunspots, high-speed solar winds, solar flares, coronal mass ejections and Halo CME. The relationship between various features that are similar during solar cycles 23, 24 and 25 is examined in the current paper. According to the study, there is still a strong correlation between different parameters that point to a common origin. The factors affecting solar activity determine whether a cycle is at its maximum or minimum. From this study Compared to solar cycles 24 and 25, the annual averaged solar wind is at its highest during solar cycle 23. In solar cycle 23, the solar wind reached a maximum speed of 543 km/s, while in solar cycle 24, the maximum solar wind reached a speed of 455 km/s. The correlation of the yearly solar indices with sunspot number shows that mean value of the solar indices is minimal in solar cycle 24 and 25 with the maximum indices value as for the solar cycle 23.

Keywords: Solar Cycle, Sunspots number, solar flares, Solar Fux, Coronal mass ejection, Halo CMEs, Solar Maximum, Solar Minimum

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1. INTRODUCTION

The sun is a vigorous star and changes on time scales extend from minutes to billions of years. The solar atmosphere is one of the richest and most dynamic environments studied in modern astrophysics. Like earth, the sun has seasons. More precisely, it has a cycle that lasts about 11 years. The number of sunspots rises and falls and rises again in about 11 years. This is due to the variability of solar magnetic field. The variability of the magnetic field has a strong influence on the dynamics of the outer layer of the sun and is registered by several solar parameters such as the sunspot number, CME occurrence, High speed solar wind and Solar flare. The solar activity parameter variability from one cycle to the next and geomagnetic records shows the difficulty in making empirical predictions of both types of activity. In the present work, we have analyzed the solar output variability during solar cycle 23 to 24. The 23 solar cycle is begun from August 1996 and ending in December 2008. In the solar cycle 24, which has its beginning in December 2008 and the cycle is ended in December 2019.

The solar cycle is an increase and decrease in the number of sunspots that can be seen on the surface of the sun, with a maximum number of sunspots occurring every 11 years. The average number of sunspots visible over the surface varies from a minimum near zero to a maximum of about one hundred over the course of the solar cycle, an 11-year magnetic cycle. The sun experiences a solar minimum, which is characterized by fewer, smaller sunspots, prominences, and flares, and a solar maximum, which is characterized by more, larger sunspots, prominences, and flares. The magnetic field poles reverse after 11 years. The sunspots are the most easily observed and have been tracked since around early 1600s by Galileo. The sunspots can come into view as solitary, remote dark central region covered by a regular less dark region around umbra (Spiegel, 1994). Since last four hundred years, the periodic changes in the Sun's activity were featured with smoothed sunspot numbers that was brought into existence with its classification (Kunzel, 1961). The number predicts short term periodic high and low activity of the Sun. The part of the cycle with low sunspot activity is referred to as "solar minimum" while region with maximum solar activity is called as "solar maximum". Hathaway et al. (2002) examined the 'group' sunspot number which shows it use in featuring the Sun's performance during the solar year (Hoyt & Schatten, 1998). Coronal mass ejections (CMEs) are the explosions in the solar corona during its high magnetic conditions. CMEs from the solar corona are the most spectacular phenomena of solar activity and perhaps the primary driver and source of space weather (Gosling, 1997; Singh et al. 2010). Traditionally, the coronal mass ejection ejects away around 10^{10}-10^{17}g of the core which gives out the energy of the order ($\sim10^{19} - 10^{25}$ J) (Chen, 2011; Howard et al. 1985; Vourlidas et al. 2002). Coronal mass ejections are the most spectacular phenomenon of solar activity. CMEs occur in regions of closed magnetic fields that overlie magnetic inversion lines. A study on CME is an important topic that is related directly to space environment. The sunspot cycle is an important form of solar variability that indicates the extent of closed magnetic field structure on the sun, and hence is important to the study of the origin of coronal mass ejections.

Gopalswamy et al., (2009) made a revision for the relation between coronal mass ejection and numeral spot number on the surface of the Sun and they found that the relation between them was weak during the maximal stage of the astrophysical cycle whereas in the uprising and the downfall time of the astrophysical cycle the trend is not the same. Sharma & Verma (2013) also revised the link among the various solar characteristics. For the present work, the analysis has been done among the correlation between the parameters and comparing the variation pattern with in the solar cycle 23 (1996-2008), Solar cycle 24 (2009-2019) and Raising phase of Solar cycle 25 (2020 - 2023). CMEs that are launched towards the Earth are called halo CMEs because as they approach the Earth, they appear larger than the Sun, making a 'halo' of bright coronal emission completely around it. Partial halo CMEs occur at a rate of about 10 % that of all CMEs, but 360° halo CMEs are only detected at a rate of ∼4% of all CMEs (Gopalswamy et al. 2010). It has been documented that halo CMEs appear to be faster and more energetic than non-halo CMEs. This, of course, does not imply that halo CMEs are somehow physically different, but rather it shows that even with LASCO, some CMEs are not detected (Gopalswamy et al.2010). Large structures containing plasma and magnetic fields called coronal mass ejections (CMEs) are ejected from the sun into the heliosphere.

The likelihood that CMEs will directly affect the Earth when they occur close to the solar disc center makes them useful for forecasting geomagnetic storms. A subset of front side CMEs is a halo CME, which is a bright coronal emission 'halo' that completely surrounds the Sun. They grow quickly and seem to encircle the observing coronagraph's occulting disk. Halo CMEs were routinely observed by the Large Angle and Spectrometric Coronagraph (LASCO) on the Solar and Heliosphere Observatory (SOHO) mission. We only considered halo CMEs with 360 widths in this paper.

The solar wind is a stream of charged particles released from the upper atmosphere of the Sun. This plasma consists of mostly electrons, protons and alpha particles. The magnetic field of the Sun, as well as different structures, waves and turbulent fluctuations on a wide range of scales are embedded within the solar wind. Being the continuation of the solar corona, the solar wind displays periodic behavior that may be caused by the Sun's regular variations. Numerous studies on the variations of solar parameters, including interplanetary parameters like the IMF, solar wind velocity, plasma density, and plasma temperature, have been conducted in the past. In various solar cycle phases, various solar parameters are visible. All parameters share some periodicities, while others are found to change with the solar cycle.

Solar flares are the result of complex magnetic phenomena, seen as a sudden and intense brightening on the solar disk. They are the result of the rapid conversion of a large amount of magnetic energy, stored for a while in the solar corona, and dissipated through magnetic reconnections. Solar flares are the other class of the most spectacular disturbances seen on the Sun, typically lasting several minutes. It can be defined explosive release of energy of order same as CME ($\sim10^{19} - 10^{25}$ J) from a localized active region of the Sun, mainly with the appearance like electric and magnetic field radiations containing X-rays, UV rays, visible light, and radio waves. Flares takes place in lively area just about sunspots, here the strong field containing magnetic character go through the photosphere to interact with the corona. The association of solar flares and CMEs have been widely (Gopalswamy, 2006). Solar flux is also fundamental pointer of the Sun’s performance that helps to find out the level of radiation obtained from the Sun.

The solar flux (10.7 cm) unit is solar flux units (SFUs), where 1 SFU = 10^{-22} Watts per meter 2 per Hz. Astrophysical storm is a river of plasma consists mainly of negative charged particle, positive charged particle and alpha-particles, ejected from the higher environment of the Sun. The attractive region was depicting the annual happening rate of regularity of the coronal mass ejections (CME) shown in SOHO LASCO directory. A 10.7 cm solar flux measurement is a determination of the strength of solar radio emission in a 100 MHz-wide band centered on 2800 MHz (a wavelength of 10.7 cm), averaged over an hour. It is expressed in solar flux units (sfu), where 1 sfu = 10^{-22} W m^{-2} Hz^{-1}. The solar radio flux at 10.7 cm (2800 MHz) has been an excellent indicator of solar activity. Usually called as the F10.7 cm index, it is one of the longest running records of solar activity (Kenneth 1990). The F10.7 radio emissions originates high in the chromosphere and low in the corona of the solar atmosphere. The F10.7 correlates well with the sunspot number as well as a number of ultra violet (UV) and visible solar irradiance records.

2. DATA USED

The sunspot, solar wind and solar flux information has been taken from the link: http://omniweb.gsfc.nasa.gov/form/dx1.html. The CME and Halo CMEs data used in this study is collected from LASCO and SOHO available in CME catalogue that can be found at http://cdaw.gsfc.NASA.gov/CME. The solar flare data is collected from http://www.ioffe.ru/LEA/solar/index.html.

3. RESULT AND DISCUSSION

The graph depicts the variation in various solar parameters over solar cycle 23 (from 1996 to 2008), solar cycle 24 (from December 2008 to 2018) and solar cycle 25 (up to year 2022). Each solar parameter data is split in to three phases, they are Raising phase, Maximum phase and Decline phase. Sunspot, Coronal Mass Ejection, solar flare, solar flux, solar wind and Halo CME are statistical indicators. The majority of studies in this field have found that the sunspot number is a reliable indicator of long-term solar activity. The photosphere and coronal phenomena of the solar atmosphere, which are regularly reported in the Solar Geophysical Data, are explained by solar activity. With access to solar data through numerous open access websites, it is appropriate to look into how different solar indices are related to one another and to determine the right parameter.

3a. SOLAR FLARES

Figure(1a) The first significant factor is the rise in flare activity brought on by the active area. As the rate of increase in the magnetic field has noticeably slowed down toward the middle of solar cycle 23 in the year 1998, the solar cycles 23, 24, and 25 are characterized by their flare activity. The sunspot and flare activity, however, grew more active at the same time. The table displays the intense solar activity along with various solar flare types. According to this observation, the M-class flare, C-class flare, X-class flare, and B-class flare all reached their highest peak in 2013. They are four flares of the appropriate types and values.

A sharp rising of the flare activity in the solar cycle 23 in the magnetic field starting in 1996 is accompanied by increasing sunspot and flare activity. Correspondingly, the rising phase of solar cycle 23 in the year 1996 with their type of flare activity as for M and X. Hence there is zero flare activity for C and B flares. It was found that the year 1997 was a minimum number of active flares is 18 than the year 1998 number of active flares. The total number of flares in this year is obtained as 61. This year's active flares are M, C, and X, and there have been no B-class flares. The flare values for the solar years 1996, 1997, and 1998 are displayed. However, data from 1998 indicates that the maximum value of flare activity was 61, with the rising phase being where activity peaked. Since the beginning of solar cycle 24 in 2009, there has been no flare activity. Following the year 2009, the number of flare activities in 2010 is 7. Flares M and C are currently active. There are six M-class flares that are currently active, compared to one C-class flare. Similarly In the most recent solar cycle 25, the rising phase of 2020, there is one active flare with the active flare number being C. In 2021, there are 6 active flares; the M, C, and X have 1, 3, and 2 active flares, respectively. More specifically, in the year 2022, the maximum number of flare activity is 32. As the active flares are M, C, and X, with corresponding values of 20, 7, and 5. The comparison of the rising phase of the cycles leads to the conclusion that solar cycle 23 has the highest flare activity, compared to solar cycles 24 and 25.

In solar cycle 23, the maximum solar flare activity has two peaks. the first maximum phase of solar cycle 23, which lasted from 1999 to 2001, and the second maximum phase, which lasted from 2002 to 2004. The total number of flare activity for the year 2001 was 111, and the active flares had M, C, and X flare values of 65, 31 and 15, respectively. when the number of active flares in the years 1999 and 2000 is less than the number in the year 2001 because there were 85 and 106 active flares in these two years, respectively, as opposed to 111 in 2001. Similar to solar cycle 23, the peak value in solar cycle 24 occurred between the years 2011 and 2014, but the maximum peak value occurred in 2014 with 67 flares, while flare activity in the other years was lower than in 2014. The number of active flares in 2011, 2012, and 2013 is 42, 40, and 55, respectively. Thus, in solar cycle 24, 2014 saw a high in flare activity.

The declining phase of the Sun is probably undergoing a phase of weakened activity i.e., a gradual decline in peak solar activity) during the past three SCs. Several studies have suggested that this declining phase will continue, and the upcoming SC 25 would be still weaker compared to SC 24 (Hathway and Wilson, 2004; Janardhan *et.al*; 2015b). The decline phase of Solar Cycle 23 began in the years 2005 and continued through 2008, with a slight annual decline in flare activity. In 2005, there were 37 flares; in 2006, there were only 12, down from 37. The flare activity gradually decreased after the year 2006, reaching 5 in 2007 and 0 in 2008. In solar cycle 24, there are fewer flares than there were in cycle 23. The number of activities in solar cycle 23 have decreased since the year 2015, and there will be none in 2019. There were 38 different activities in 2015. From the year 2015, there was a slight decrease in activity. In 2016, there were four activities, and after that, they increased to fourteen in 2017 and then decreased to one in 2019.

3b. CORONAL MASS EJECTION

Figure(1b) displays a plot of the number of coronal mass ejection (CME) events that occur each year in the SOHO and LASCO directories. A maximum CME can occur at a very wide range of rates during the 23rd solar cycle. The data shows a broad level beginning in the years 2000-2002 and 2005-2007, during which the maximum value is attained and it then slowly starts to decline. The CME frequency has been rising steadily and hasn't reached its peak yet. It also emerged that, in contrast to other years, there were more entries relating great CMEs events during the events of 2000–2002 and 2005–2007. For the CME events, the solar cycle 23 obtained a twin peak. In the years 2000, 2001, and 2002, the maximum phase of CME events was 1661, 1494, and 1696. Then, in the years 2005, 2006, and 2007, there were three additional maximum peak events: 1247, 1045, and 1436. The solar cycle 23 lasted for roughly 13.5 years, but compared to next solar cycles, it is regarded as weak. Shows the yearly occurrence frequency (Rw) of the coronal mass ejections (CME) given in SOHO – LASCO catalogue in solar cycle 24. The lowest frequency in maximum phase has been in 2011 the occurrence of frequency is 1963. The frequency increases in the year 2012 to a maximum of occurrence 2014 is obtained. In year 2013 CME frequency increases further, reaching a maximum number of 2302 events. Shows a similar plot for maximum value of sunspot number (Rz (max)) during the same period. In 2014, the sunspot number was 113. Like CME, sunspot number was much higher in the year 2014.

When compared to other types of solar activity, the frequency of CME occurrence exhibits nearly identical variational pattern. The time in which the rising phase for solar cycles 23, 24 and 25 along with specific CME occurrence values. In 1996, there were 205 CME events, which marked the beginning of the solar cycle 23 rising phase. In 1997, there were 385 CME events, which marked the peak of the phase. 716 CMEs were the highest event since 1997, which raised the bar after that year beginning with the maximum phase. This suggests shared origins, likely caused by magnetic configurations that are similar across the board and have an immediate impact on all parameters. It may also be related to the fact that CMEs come from both sunspot regions and non-sunspot regions. Ramesh & Rohini, (2008) and Ramesh (2010) have shown that CME frequency is better

Table1 shows the yearly averaged data of solar parameters like sunspot number, solar wind speed, solar flux, solar flare, CME and Halo CME in solar cycle 23, 24 and 24

Solar Cycle	Year	Solar Parameters					
		Sunspot Number	Solar Wind Speed	Solar Flux	Solar Flare	CME	Halo CME
23	1996	12	423	72	2	205	4
	1997	29	381	81	18	385	17
	1998	88	410	118	61	716	28
	1999	136	439	154	85	1015	14
	2000	174	448	180	106	1661	57
	2001	170	426	181	111	1494	63
	2002	164	440	179	90	1696	52
	2003	99	543	128	85	1130	30
	2004	65	451	107	75	1099	40
	2005	46	473	92	37	1247	59
	2006	25	431	80	12	1045	14
	2007	13	441	73	5	1436	3
	2008	4	450	69	0	861	1
24	2009	5	364	1	0	742	1
	2010	25	403	11	7	1103	11
	2011	81	420	41	42	1963	41
	2012	84	408	83	40	2124	186
	2013	94	397	55	55	2302	55
	2014	113	398	66	67	2460	66
	2015	70	437	40	38	2048	40
	2016	40	446	12	4	3080	12
	2017	22	455	9	14	783	9
	2018	7	412	1	0	470	1
	2019	4	398	1	1	539	1
25	2020	9	378	0	1	647	4
	2021	30	403	16	6	537	16
	2022	135	442	17	32	428	17

coronal mass ejection's annual occurrence frequency (Rw). The CME's lowest 742 in the year 2009, and its highest frequency, 1103 a year 2010, was reached. As the same this study explains the CME activity for solar cycle 25, yielding a maximum rising phase event of CME with a frequency of occurrence of 647 for the year 2020. The CME event will continue to grow after 2020. In the year 2022, there will be 428 events, a decrease from the year 2021's 537 events.

Solar cycle 23's CME activity will continue to decline between the years 2003 and 2008, when it will reach its lowest point. In terms of activity, the solar cycle 23 has two peaks so it's also had two decline phases. First peak decline phase with 1130 and 1099 CME events in 2003 and 2004 is decelerated. In 2008, there were 861 CME events, marking the second peak decline phase in their solar activity. Following that, from 2015 to 2019, solar cycle 24 will see a decrease in solar activity. The maximum value of the decline is 2048 in the year 2015, and after that year, it gradually declines as solar cycle 24 activity occurs more frequently. Their findings indicated that the minimum would occur between 2017 and 2019. They predicted that the activity of CMEs is would peak in the year 2016 with 3080 events, continue to decline in 2017 with 783 events, and finally decline to 470 and 539 events in the years 2018 and 2019.

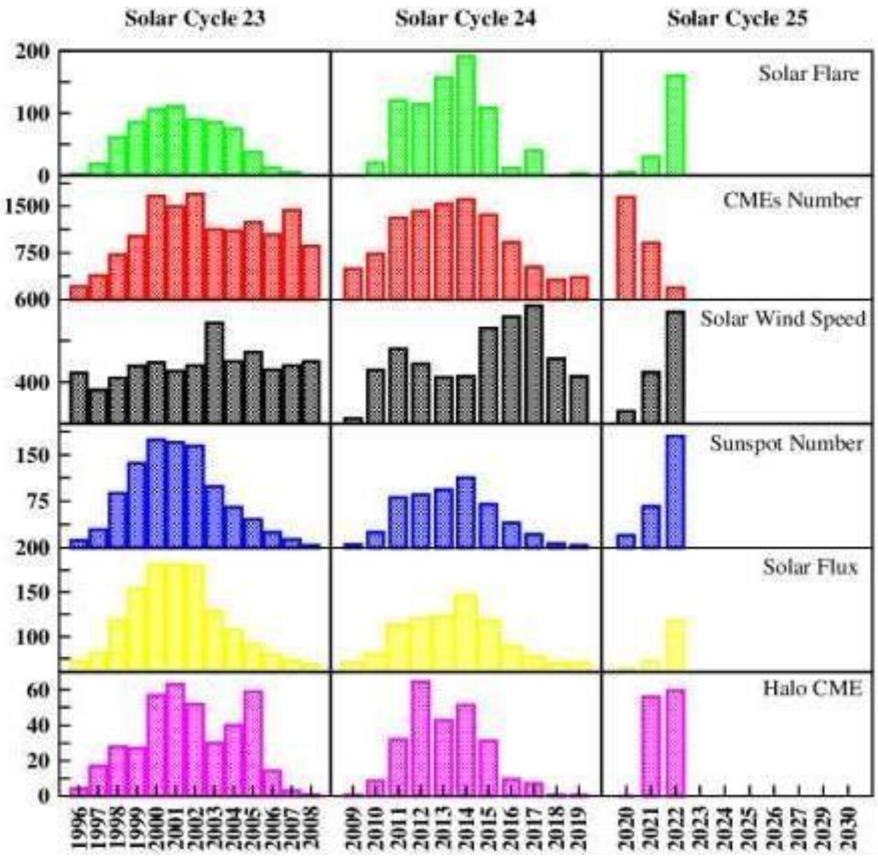
3c. SOLAR WIND

Based on the necessary information, the behavior of the solar wind parameters of solar cycles 23 to 25 is investigated. The information is chosen based on solar cycle phases and the types of large-scale solar wind phenomena. The investigation revealed that during the rising, maximum, and lowest phases of solar cycles 23–25, the parameter values changed depending on the solar wind and continued to remain low. Figure(1c) The fluctuation of several solar parameters during solar cycles 23, 24, and 25 is depicted in the figure. In the Rising phase, the rising phase of solar cycle 24 is depicted in a lot that is similar to that in the minimum value of SN from December 2009 to December 2019 was 4. Maximum phase, and Minimum phase of these solar cycles, the figure depicts the sun with and solar activity. The annual average solar wind in km/s from 1996 to 2008, 2009 to 2019 and 2020 to 2022. The solar wind speed was 423 km/s when solar cycle 23's Rising phase began in the year 1996. After 1996, the solar wind's velocity changed regularly, increasing and dropping somewhat before reaching a maximum of 448 km/s in the year 2000. Similar to this, in solar cycle 24, the rising phase began in 2009 with solar wind speeds of 364 km/s and gradually increased until it reached 420 km/s in 2011. The solar wind fluctuates slightly between these years, rising and falling, and then slowing down in 2012 compared to 2011.However, from 2019 to 2022, during solar cycle 25, the solar wind speed steadily increases from 378 to 442 km/s.

The peak years of these solar cycles include 2003, when solar cycle 23 had the highest solar wind speed of 543 km/s, and 2017, when solar cycle 24 had the highest solar wind speed of 455 km/s. This is due to the fact that at the solar maximum, CMEs and SEPs that originate from the regular solar wind interact with the magnetosphere. 2017 is the year with the highest solar wind speed. There is no minimum wind speed in solar cycle 23, and the speed barely varies little from year to year. However, in solar cycle 24, the solar wind's speed is at its lowest in 2018 and 2019, at 412 and 398 km/s, respectively. When the wind speed is high, the overall number of CMEs is similarly high, according to a comparison between the annual average wind speed and the annual average CME number.

3d. SUNSPOT

Figure(1d) shows the sun is extremely active, with a high number of sunspots. Figure depicts how often sunspots appear during the solar cycles 23, 24, and 25's ascending phases each year. The solar cycle 23 has seen the fewest sunspot events, 12 in total. In the years following 1996, the value of SN continues to increase in the year 1997 with 29 and reaches a maximum of 88 in the year 1998. The number of sunspot activities also gradually increases during these years.



Figure; 1. Variations of (a) solar flare, (b) CME'S number, (c) solar wind speed, (d) sunspot number, (e) solar flux (and f) Halo CMEs during the solar cycle 23, 24 and 25.

For an example, SN's rise to 81 in 2011 from a much higher level in the phase just before it is intended. The sunspot activity is then at its peak when compared to the rising phase of solar cycle 25, which begins in the year 2020 and has an SN of 9. It is once again obvious that solar cycle 25's 29.6 sunspot rates in 2021 are significantly higher than those in 2020. The cycle is creating more sunspots and increasing their activity. Take note of the solar cycle 25's first year's unusually low SN rate. The SN is worth 66.8 in 2022.

Here, it is known that Sunspot activity will be greater than in the past year, and possibly that solar cycle 25 will be more powerful than solar cycle 24. We have inferred that the next solar cycle (cycle 25) will start in 2021 (January) and would last till the year 2031 (February) while the maxima of the cycle would reach around the year 2024 (February) with sunspot numbers A.K. Singh and A. Bhargawav. (2019). The maximum number of sunspots during solar cycles 23 and 24, respectively, from 1999 to 2001 and 2012 to 2014.

A first SN maximum of 136 is shown in cycle 23 in the year 1999, which is a little earlier than the SN maximum of 1999, and a second SN maximum of 174 is shown in the year 2000. The sunspot had a significant peak in 2001, with an SN value of 170. Exhibited behavior that was very different from that of earlier cycles for cycle 23. The maximum solar activity and the maximum SN both occurred in 2001. The progression of solar maximum-area sunspot activity. Alike The sunspot experienced a significant peak in solar cycle 24 in 2014, with an SN value of 113. The major peak value is greater than the first and second maxima values. The calculated sunspot value for 2012 and 2013 is 85 and 94, respectively. Most other indices also display two maxima within a month or two of the sunspot maxima when there are two maxima in sunspots. The second maximum in the other solar indices, however, can occasionally be greater than the first maximum, in contrast to sunspots where the second maximum is equal to or smaller. There is typically only one noticeable sunspot maximum in (11-year) cycles, but occasionally there is a wide plateau. When referring to the ends as the first and second maxima, the first maximum is always larger. Between the two maxima, there is a very small valley. Similar patterns can be seen in indicators that originated at or near the photosphere. Most other indices also display two maxima within a month or two of the sunspot maxima when there are two maxima in sunspots. The second maximum in the other solar indices, however, can occasionally be greater than the first maximum, in contrast to sunspots where the second maximum is equal to or smaller.

Explore the solar activity like sunspot for the decay phase of the cycle 23 and 24 using the data for the sunspot number. The speculate that a solar cycle 23 from year 2002-2008 and solar cycle 24 from the year 2015-2008. Sunspot minima during the years 2002 to 2008 could be brief and distinct, lasting one or two months, or they could last for several months. In year 2003, the annual SN for solar cycle 23 peaked at a value of 99 before rapidly declining until the following sunspot minimums. In 2008, the solar cycle 23 reached its minimum value of 4. Similar variations of SN to the declined phase from the years 2015 to 2019 can be found in Solar Cycle 24. The SN values were 70 at the beginning of the declined phase and were reduced to 40, 22 at the end of the cycle, with the SN nearing their minimum and completely declining 7 in 2019. In some cases, minima earlier than sunspots are seen, while in some other cases minima occur after the sunspot minima. Thus, the energy dissipation in the upper part of the solar atmosphere sometimes lags or leads the evolution of sunspots near sunspot minimum. In a few cases, after the minimum, the indices recover faster than the sunspots. R. P. Kane. (2002).

Regarding sunspot minima, Harvey and White (1999) made an interesting investigation for cycles 22–23. They concluded that cycle minimum is not defined solely on the basis of the occurrence of the minimum in the smoothed sunspot number, but rather by several additional parameters, including the monthly (or rotationally) averaged sunspot number, the number of regions (total, new- and old-cycle), and the number of spotless days, and recommended that the minimum between cycles 22 and 23 should be considered as to have occurred in September 1996 and not in May 1996.

3e. HALO CME

Figure(1e) The comparison of the Halo CME for solar cycles 23, 24, and the solar cycle 25 was done using the annual average. The halo CMEs with 360° width are the only ones taken into consideration in this paper. A comparison of the number of halo CMEs observed each year from 1996 through 2008, 2009 through 2019, and 2020 through 2022 has been made. The table lists the number of halo CMEs that were observed each year from 1996 through 2008, 2009 through 2019, and 2020 through 2022. It demonstrated the variation in halo CME numbers seen during the aforementioned years. It was discovered that 382 cases of halo CMEs were recorded from 1996 to 2008. which suggested conditions for solar maxima. Between 2009 to 2019, 423 halo CMEs were obtained in total. While 37 halo CME events occurred between 2020 - 2022. In solar cycle 24, the observations mentioned above showed greater solar activity than those from 1996 to 2008 and 2020 to 2022. They expand rapidly and appear to surround the occulting disk of the observing coronagraph. The solar and heliosphere observatory (SOHO) mission's Large Angle and Spectrometric Coronagraph (LASCO) routinely observed Halo CMEs (Brueckner et al. 1995).

From the years 1996 to 1997, solar cycle 23's rising phase was calculated. In corresponding years, the Halo CME is observed as 4 to 17. The rising phase in solar cycle 24 from the years 2009 to 2010 has the values raised from 1 to 11, respectively. The first and third Halo CME cases in the solar cycle 25 rising phase are in 2020 and 2022. It showed that the maximum phases of solar cycle 23 were from 2000 to 2002 and 2004 to 2005 in terms of the number of halo CMEs that were observed each year. There was total 172 and 99 cases of halo CMEs observed from these years, respectively, according to the variation of the number of halo CMEs (width = 360) observed during the years 2000 - 2002 and 2004 - 2005. Declining of the solar cycle 23 Halo CME occurred from the years 2006 to 2008 with 2, 1, and a minimum case of zero. Similar to solar cycle 24, a total of 4 halo CMEs were seen between 2015 and 2019, but only one per year, indicating solar minima conditions.

3f.Graphical representation of M, C, X and B type of flares in the 23, 24 and 25 Solar Cycle.

Solar flares are thus classified using the letters M, C, X and B depending on their X-ray peak flux in the wavelength range from 0.1 to 0.8 nm. X class flares are major events with very intense luminosity and a large amount of X-ray flux in the order of 10^{-4} Wm $^{-2}$. M class flares are less bright

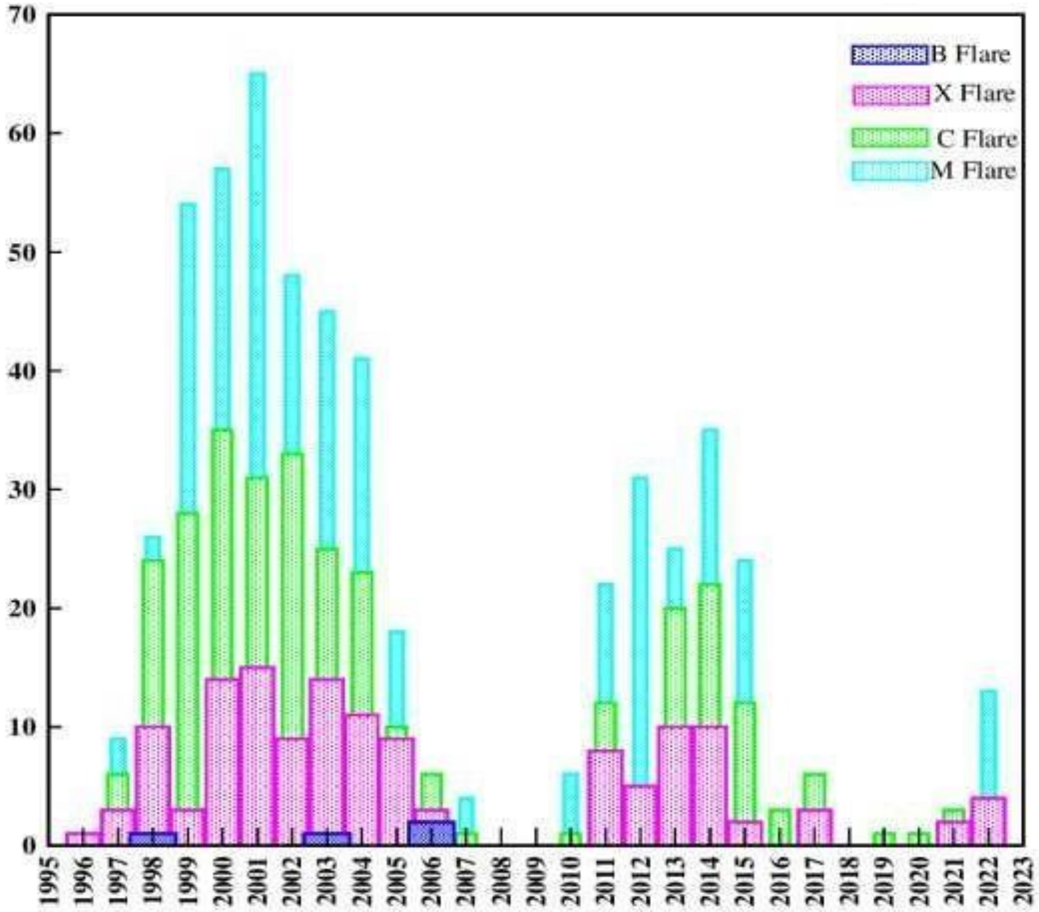


Figure 2 Types of solar flares

Table2 shows that the type of flares and the yearly averaged values of M, C, X and B type flares in solar cycle 23, 24 and 25

Year	M-type Flare	C-type Flare	X-type Flare	B- type Flare
1996	1	0	1	0
1997	9	6	3	0
1998	26	24	10	1
1999	54	28	3	0
2000	57	35	14	0
2001	65	31	15	0
2002	48	33	9	0
2003	45	25	14	1
2004	41	23	11	0
2005	18	10	9	0
2006	1	6	3	2
2007	4	1	0	0
2008	0	0	0	0
2009	0	0	0	0
2010	6	1	0	0
2011	22	12	8	0
2012	31	4	5	0
2013	25	20	10	0
2014	35	22	10	0
2015	24	12	2	0
2016	1	3	0	0
2017	5	6	3	0

2018	0	0	0	0
2019	0	1	0	0
2020	0	1	0	0
2021	1	3	2	0
2022	20	7	5	0

with X-flux greater than 10^{-5} Wm^{-2}; they are capable of inducing hard electromagnetic emissions and radio emission (solar radio bursts), which affect low-orbital spacecraft and ISS (Zalnol, N.H *et al.* 2016). The other class B is low-luminance particles that have little effect on the Earth's ionosphere.

The M flare is shown to be more active than the other three types of flares in the 23rd 24th and 25th solar cycles in the graphical representation of flare types. However, the M- class flare peaks in the year 2012, the 24th solar cycle rather than the year 2001 of solar cycle 23. Its peak value is within the category of flares like C, X, and B minimum than the M flares in both solar cycles. However, there were more flares in solar cycle 23 than in solar cycle 24. The classification and comparison of the solar flux analysis with the smoothed sunspot number each year (SSN).

Depending on how frequently they occur, solar flares are divided into three categories. In this found that the C-class flare, M-class flare, and X-class flare all reached their maximum peaks in solar cycle 23 in 2001, with corresponding values of 31, 65, and 15 respectively.

Additionally, the solar cycle 24 maximum peak was recorded in the years 22, 35, and 10 in 2014, it is seen that the SSN increases before decreasing. The C, M, and X class flares have exhibited the same pattern for the longest period of time. Similar to solar cycle 25, only one C type flare is active in 2020. Then, in 2021, there are three different types of flares: M, C, and X, with corresponding numbers of 1, 3, and 2. The maximum number of flares that will be active in 2022 will be 32. when there are respectively 20, 7 and 5 M, C, and X flare cases during active flares.

3g. Correlation of solar activity parameters with sunspot

Solar Activity Parameter	Correlation With Sunspot		
	Solar Cycle 23	**Solar Cycle 24**	**Solar cycle 25**
Solar Flux	0.9982	0.9893	0.9901
Solar Flare	0.9537	0.9703	0.9906
High Speed Solar Wind	0.129	0.0534	0.9939
Coronal Mass Ejection	0.6330	0.9820	-0.9716
Halo CME	0.7809	0.9291	0.7601

The relationships between various measurements of solar activity parameters for solar cycles 23, 24 and 25. It is evident that the relationship between sunspots and solar variables such as solar flux, solar flare, high-speed solar winds, coronal mass ejection, and Halo CMEs is strong. In 23rd solar cycles, the correlation coefficients for these parameters were found to be 0.9982, 0.9537, 0.129, 0.6330 and 0.7809 respectively. Corresponding correlation coefficient for solar cycle 24 with suitable values 0.9893, 0.9703, 0.0534, 0.9820 and 0.9291. Additionally, it was discovered that the correlation coefficients for the 25th solar cycles were 0.9901, 0.9906, 0.9939, -0.9716 and 0.7601 respectively.

4. CONCLUSION

In this research, the solar cycles 23, 24, and 25 were analyzed in relation to variables indicating solar activity, including sunspots, solar flux, solar flares, high-speed solar winds, CMEs, and halo CMEs. Investigation done using these factors' yearly average values. Studies of the activity of parameters reveal characteristics of progression, including which solar cycle is more active or not, as well as the strength and duration of the rising phase, maximum phase, and declining phase in comparison to other solar cycles. Recently, it has been demonstrated that the cycles mentioned above offer the distinctive data needed for this analysis. The investigation of these indicators' levels of activity can also be used to identify the antecedent causes of fluctuations in solar activity.

- Less activity is present at the beginning of solar cycles 24 and 25 than in cycle 23.
- Between 1996 and 2008, the 23rd solar cycle had 12 to 4 sunspots per year. While it was noticed that it went from 5 to 4 from 2009 to 2019. Accordingly, in compared to the years 2009 to 2019 and 2020 to 2022, the solar activity was more pronounced between 1996 and 2008 than it was between those years and the number of sunspots in solar cycle 24. Between 2020 and 2022, the measured sunspot ranged from 9 to 135 during solar cycle 25.
- From 1996 to 2008, the solar radio flux (F10.7cm index) ranged between 72 and 69, while from 2009 to 2019 it varied from 1 to peak at 83 and then decline to 1, indicating that solar cycle 23 was more pronounced in terms of solar activity than solar cycles 24 and 25. Between 2020 and 2022, the range is 0 to 17.
- In the years 1996 and 1997, the events are 4 and 17 instances of halo CMEs (width = 360) Were seen respectively, but the value of final year 2008 of solar cycle 23 and the beginning of 2009, which indicated solar minima for these years. A total of 382 halo CMEs were recorded between 1996 and 2008, 423 halo CME occurrences between 2009 and 2019, and a total of 37 incidents between 2020 and 2022. Once more, this showed that solar cycles 24 and 25 had less visible halo CME activity.
- The frequency of CMEs and the number of sunspots on the surface of the sun were in good accord. With an increase or decrease in sunspot number, CME occurrence rates rise or fall.
- The highest solar flare occurred in the year 2001 during Solar Cycle 23, whereas the lowest flares occurred in the years 1996 and 2008. When compared to solar cycle 24, the number of flares per year is at its highest in 2014 with 67 and at its lowest in 2009 and 2018 with nil, respectively. In contrast to solar cycles 24 and 25, the number of flares is highest in solar cycle 23.
- Compared to solar cycles 24 and 25, the annual averaged solar wind is at its highest during solar cycle 23. In solar cycle 23, the solar wind reached a maximum speed of 543 km/s, while in solar cycle 24, the maximum solar wind reached a speed of 455 km/s.
- When the yearly solar indices are correlated with the sunspot number, the mean value of the solar indices is minimal in solar cycles 24and 25, with the maximum value in solar cycle 23.

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