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Research Article

Long-Term Variations In The Interrelationships Between HCME And North Atlantic Oscillations As An Indicator Of Climatic Variability`

Farghaly, Magda[1*], Tharwat, Assem[2]

[1*]National Researches Institute for Astronomy and Geophysics, Egypt, Email:-mohebmagda@live.com
[2]Synergy University Dubai, UAE, Email:-assemtharwat@hotmail.com

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ABSTRACT

The influence of sun variability on the Earth's climate requires studying sun interactions, and mechanisms that designate the response of the Earth's climate system. The NAO (North Atlantic oscillation) is taken into consideration as one of the maximum dominant modes of global weather variability. Like El Niño, La Niña, and the Southern Oscillation, its miles are considered as loose inner oscillations of the climate device now not subjected to outdoor forcing. It is shown, to be linked to energetic sun eruptions.

Many Studies suggest that solar hobby features are associated with El Niño and La Niña, without a doubt have a large effect on the North Atlantic Oscillation (NAO). A hemispheric meridional oscillation is an atmospheric mass with facilities of movement close to Iceland and over the subtropical Atlantic, which can be furnished as top -bottom mechanism. Sunspot area and coronal mass ejections (CMEs) are from the most crucial sun sports and interest signs as some distance as area climate consequences are worried, which is probably linking solar eruptions, vital interplanetary disturbances, and geomagnetic storms.

A Halo CME (HCME), which is normally related to interest near the sun disk center, has a splendid effect on area climate because an Earthward HCME is indicative of coronal mass and magnetic fields moving out closer to the Earth, therefore probable to cause geoeffective disturbances. In this paper, special statistical equipment was carried out to investigate the interrelationships among sunspot area and HCMEs with NAO index on the sun cycles 22, 23, the outcomes had been referred to expose their dependency which therefore can be used to are waiting for the conduct of NAO index inside the next solar cycles that is used as a trademark to climatic variability.

Keywords: Solar cycle, Solar Activity, NAO Index, HCME, Space Weather, Sunspot, Climate variability.

1. INTRODUCTION

The solar cycle, characterized by way of sunspots and sun flares, wields dynamic forces that significantly affect Earth's weather. Sunspots, dark patches on the sun's floor, imply heightened magnetic pastime and play an important function in regulating solar irradiance. The 11-12 months solar cycle and effective solar flares contribute to the diverse solar impacts on our planet's climate. Understanding the difficult results of the sun's hobby on weather dynamics requires a draw near of prolonged-time period fluctuations in sun behavior, influencing Earth's energy budget and prompting reactions inside the environment and oceans (Hathaway, 2015; Petrovay, 2020). This check pursuits to find out sun interest signs and symptoms and their capability relationships with the North Atlantic Oscillation (NAO) and High-Speed Coronal Mass Ejections (HCME).

High-Speed Coronal Mass Ejections (HCMEs), as a subset of sun phenomena, can affect Earth's magnetosphere and therefore have an impact on climate. The North Atlantic Oscillation (NAO), a climatic phenomenon associated with pressure differentials over the sea, is a massive aspect influencing weather patterns inside the Northern Hemisphere. Through an entire examination of correlations among solar hobby indices, HCME sports, and NAO fluctuations, this study seeks to offer critical insights into the mechanisms using weather variability (Wang & Ting, 2022).

Recognizing the interdependence of these sun and climatic occurrences is vital for refining climate fashions and improving our information on the complicated systems influencing Earth's weather over each fast and long time. This research endeavors to enhance our potential to forecast and adapt to the ever-changing international weather with the aid of unraveling the complicated dynamics of sun-weather interactions. As we delve into the reasons for climatic fluctuations, it becomes obvious that solar hobby, together with sunspots and Coronal Mass Ejections (CMEs), plays a full-size function. This observation goal is to research long-time period versions in solar interest indicators and their correlations with High-Speed Coronal Mass Ejections (HCME) and North Atlantic Oscillations (NAO). While anthropogenic greenhouse fuel emissions continue to be the primary driver of long-term global climate adjustments, knowledge of the impact of natural forcings, which include sun variability, is important for correct climate modeling (Arakawa et al., 2014).

The periodic nature of solar variability indicates it may be a source of decadal predictability for nearby climates, probably synchronizing with inner variability modes like the North Atlantic Oscillation (NAO). This study thus seeks to contribute to the know-how of the sun's effects on regional weather and their function in shaping each beyond modern climatic situations. Efforts have been undertaken these days to offer a skillful and trustworthy forecast of the real evolution of each internally generated and externally compelled additive of the weather device through comprehensive (decadal or near-time period) climate prediction. These prediction structures exhibit forecast talent over some years (Bellucci et al., 2013). Additionally, a strong benefit from initialization that extends past the externally forced climate response can be tested for numerous international areas, at least for huge multi-model ensemble systems. However, an intensive grasp of the related weather gadget's predictability and the interaction of its numerous predictability elements is lacking (Woods et al., 2022).
Because the wide variety of sun cycles is constrained and the sun sign is weak in evaluation of inner variability, it's miles hard to differentiate the eleven-year sun cycle surface signal from inner weather variability in measurements. A current study (Chiodo et al., 2019) tested the detectability of the solar cycle impact on the North Atlantic weather that initiatives onto the North Atlantic Ocean (NAO) and questioned the statistical reliability of the formerly generic influence. The purpose of this painting is to in part refute the findings of the previous observation and give sparkling, convincing evidence of a tiny however extensive solar influence on the weather of the North Atlantic, relative to internal variability. To isolate and interpret the 11-12 months solar cycle's impact on North Atlantic floor weather variability, in addition to measuring the solar cycle's contribution to local decadal potential predictability with regards to different outside forcings and internal variability throughout Northern Hemisphere wintry weather, we appoint a special set of two 10-member ensemble simulations of a current coupled chemistry–weather model. Andrews et al. (2015) used a similar experimental method, but our simulations are lots longer and comprise the auroral-electron forcing and spectral solar irradiance from the most superior sun forcing dataset presently available for weather fashions and recommended for CMIP6. Additionally, our simulations encompass a complete module for middle-environment chemistry modeling and a well-resolved shortwave radiation scheme (Drews et al., 2022).

The impact of solar interest on weather and weather variability has been the problem of several current studies. Cosmic radiation, consisting of solar cosmic rays (SCR) and galactic cosmic rays (GCR), has been accumulating sizeable proof over the past few years to guide the idea that it's miles critical for transmitting the sun hobby's influence to the lower surroundings. Still lacking, regardless of those efforts, is a comprehensive physical version that quantifies the relationship between solar interest, area weather, and climate. Furthermore, many studies on the connection between the sun and climate (Friis-Christensen & Svensmark, 1997) have confronted critical grievances. The number one mission in those investigations stems from the restrained length of the available instrumental datasets. As straightforward markers of long-term versions inside the GCR flux and solar interest, cosmogenic isotopes 14C and 10Be can be used. Both residing and fossilized bushes can be a valuable archive of weather variations for the duration of the pre-instrumental generation; the dendroclimatic technique employs tree-ring capabilities and tree-height increment, among other tree attributes, to reconstruct beyond climate variability. Because they offer multiple impartial proxy indicators, including ring width, latewood density, and ratios of strong isotopes in tree-ring cellulose, tree rings are very precious. Tree-ring growth in Northern Fennoscandia (NF) is especially prone to summer temperature, mainly on the northern timberline. Actually, for this location, more than one lengthy reconstruction of the summertime temperature variability in Northern Fennoscandian were accomplished. Dendroclimatologists have worked tirelessly for 30 years, and as a result, this place has a wealth of temperature proxy statistics protecting the mid- and overdue Holocene (Ogurtsov et al., 2022).

In cutting-edge instances, there was a surge in the availability of excessive-choice proxy records spanning the previous millennium. These records provide an increasingly robust framework for evaluating the current-day and future weather situations. Coupled weather fashions were used to simulate and characteristic a look at synoptic-scale techniques that underlie determined fluctuations in these climate statistics. Furthermore, model simulations have shown promise in distinguishing internal weather variability—that is especially pushed via the manner of ocean–environment interactions—from externally compelled climate signs. Examples of these externally forced weather symptoms encompass volcanism and sun variability. An international array of climatic and oceanographic proxies has recorded the transition over the past millennium between the Medieval Climate Anomaly and the Little Ice Age. However, the climate parameters worried inside the transition and its path (great to bad anomalies or vice versa) varied appreciably amongst areas, proxies, and seasons. Significant incoherency moreover exists within the time of the transition duration, it's far in element because of the triumphing limits of proxy facts, together with the place, seasonality, and linearity of the proxy response, further to date uncertainties (Trouet et al., 2012).

The organized motion of the Icelandic Low (IL) and the Azores High (AH) in the North Atlantic is known as the North Atlantic Oscillation (NAO). These pressure systems, for reasons that are mainly unclear, show synchronous meridional shifting, in which both centers of activity strengthen and shift northward. Over the North Atlantic, this leads to an intensified meridional pressure gradient with primarily zonal circulation. With normal warm air mass advection from the Atlantic across Europe and cold air advection northwest of the incentres, this ionization reaches Western Europe in the winter. Along with the southerly shift, there is a stronger meridional circulation and a weakening of AH and IL. It is impossible to ignore the impact of the NAO on the inter-annual variability of low tropospheric temperature since it accounts for up to 50% of the near-surface variance locally. Thus, for regional climate variability over Europe and North America, inter-decadal fluctuations in the NAO are important. The question this study seeks to answer is whether, given the anticipated human impact on the global climate system, this significant atmospheric phenomenon is susceptible to alteration. The main thesis is that a development of the NAO state that is highly relevant for the atmospheric fields and variables over a significant portion of the Northern Hemisphere may result from climate forcing caused by rising greenhouse gas concentrations. The NAO would act in this instance as a regional tool for the transfer of global climate change. Evaluating the general ability of coupled models and uncoupled yet forced atmospheric model simulations to replicate a genuine NAO is another goal of the current work (Paeth et al., 1999).

Over a broad variety of periods, the climate of the Atlantic region and the adjacent continents demonstrates significant fluctuation. It shows itself as consistent variations in surface pressure, rainfall, and ocean and land temperatures. These variations have a tremendous variety of outcomes on the surroundings and society. The North Atlantic Oscillation is most of the most well-known times of this variability (NAO). An index of the wintertime NAO has tested a huge growing fashion over the previous few long term. A strengthening of the middle-range westerlies and abnormally high or low ground stress throughout the subpolar or subtropical North Atlantic are connected to this trend. Understanding the essential mechanisms governing the NAO and its variability on all time scales is of maximum significance, given the full-size effect that those versions have on nearby temperatures, precipitation, and common temperature modifications inside the Northern Hemisphere (NH). We cover the NAO and the elements that can have an impact on its phase and amplitude on this bankruptcy, with a focal point on decadal and longer durations. The National Science Foundation is the sponsor of the National Center for Atmospheric Research. Additionally, some recent findings will be discussed that point to a connection between the warming of the tropical oceans and the current higher trend in the wintertime NAO index (Hurrell et al., 2002). The last remarks center on the extratropical North Atlantic climate's decadal variability in the northern summer. The talk is intended for a broad scientific audience, like the one that helped make the "Meteorology at the Millennium" conference a huge success.

Finally, the main aim of this work is to investigate the interrelationships among sun spots area and halo coronal mass ejections (HCMEs) with NAO index on the solar 22nd and 23ed cycles, the results were discussed to show their dependency which consequently can be used to predict the behavior of NAO index in the next solar cycles that is used as an indicator to climatic variability.

1.1. Solar Activity Indicators Related to Sunspot Variation:

1.1.1. Sunspot Area

The areas of sunspots are the most prominent feature of the development of sunspot groups. Since the size of sunspot areas depends on the magnetic field strength, accurate measurements of these areas are important. From each daily observation, the total sunspot area can be measured and a monthly average calculated. The units of sunspot area are millionths of the Sun's visible hemisphere. The largest number of high area groups usually occur one to two years before and after sunspot maximum. For comparison, the largest sunspot group on record was of the area of 6100 millionths on 8th April 1947, **Figure 1** shows the sunspot Area (Chatzistergos et al., 2022; Li et al., 2021).

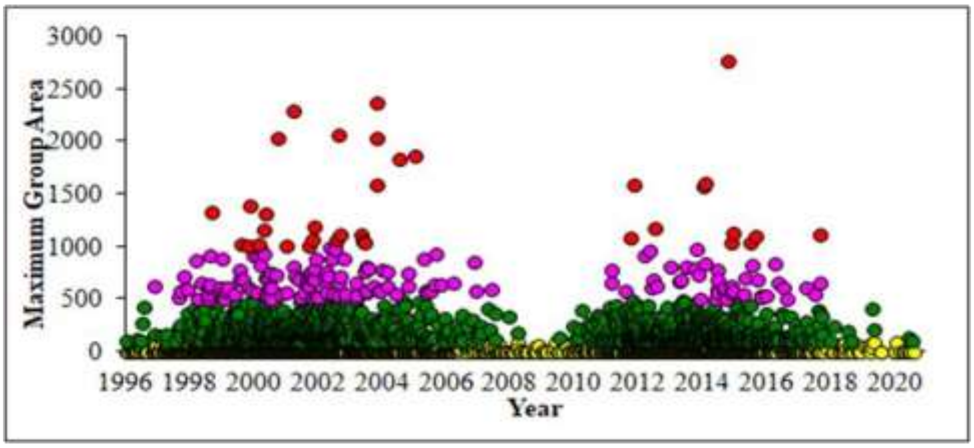


Figure 1: Illustrating the Sunspots area distribution from 1996 to 2020 [Source- Peter Meadows].

According to the above Figure sunspot area distribution from 1996 to 2020 is yellow for groups smaller than 100 millionths, green for groups between 100 millionths and 500 millionths, purple for groups between 500 millionths and 1000 millionths, and red for groups greater than 1000 millionths. Millionth of the solar disk is the unit of the sunspot area (Wang & Ting, 2022). The area of the sunspot group A m on the solar disk is calculated using (Çakmak, 2014):

$$A_M = \frac{2A_S 10^6}{\pi D^2 \cos(\rho)}$$

Where A s is the measured size of a sunspot group in the image, D is the diameter of the image, ρ is the angular distance of the sunspot center from the center of the disk. The number of spots is the number of sunspots larger than 10 millionths of the Sun's visible disk that form the active region (Baumann & Solanki, 2005; Mandal et al., 2021).

1.1.2. Coronal Mass Ejections & Halo Coronal Mass Ejections

Coronal mass ejections (CMEs) are enormous bubbles of electrified fuel that billow away from the Sun. They can deliver as plenty as 10 billion lots of solar cloth and cause incredible geomagnetic storms if they hit Earth's magnetosphere. CMEs, which usually journey at speeds between 500 and 1500 km/s, take 2 or 3 days to pass the 150 million km divide keeping apart the Sun and Earth. CMEs geared toward Earth are known as "halo activities" due to the manner they look in coronagraph snapshots. As the increasing cloud of an Earth-directed CME looms large and large it appears to envelop the Sun, forming a halo around our big name (Lin & Chen, 2022; Shen et al., 2022). Composite of STEREO-A and B snapshots from the SECCHI devices of the CME of 12 December 2008, as proven in **Figure 2.**

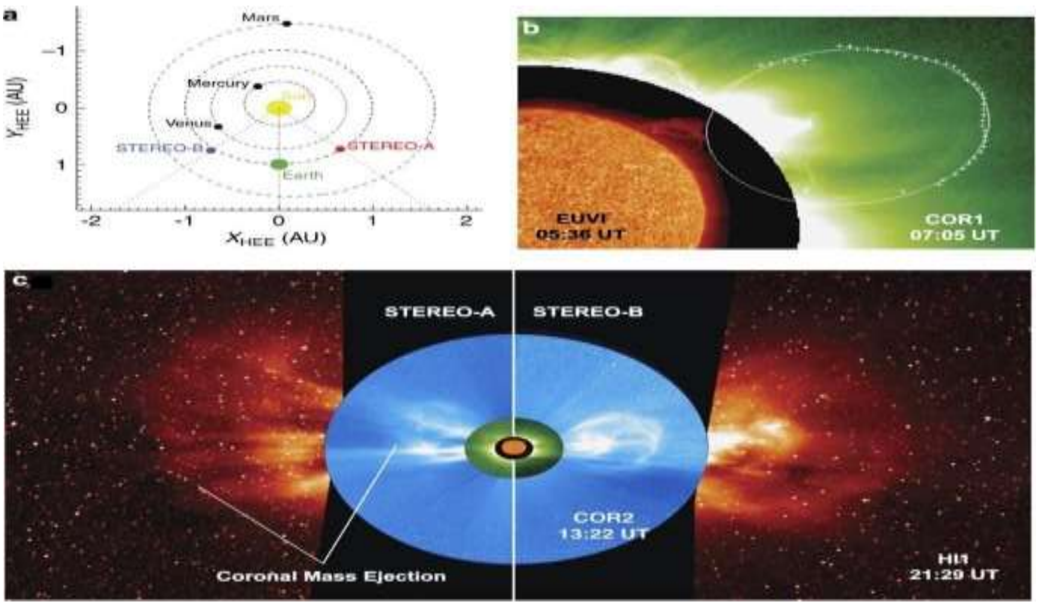


Figure 2:
(a) Indicates the STEREO spacecraft places, separated with the aid of a perspective of 86.7° at the time of the event**.**
(b) Indicates the prominence eruption found in EUVI-B off the northwest limb from approximately 03:00 UT, which is considered to be the inner cloth of the CME. The multi-scale edge detection and corresponding ellipse characterization are over plotted in COR1**.**
(c) Indicates that the CME is Earth-directed, being found off the east limb in STEREO-A and off the west limb in STEREO-B**.**

Solar coronal mass ejections (CMEs) are the maximum tremendous drivers of detrimental space climate on Earth, but the physics governing their propagation via the heliosphere isn't well understood. Although stereoscopic imaging of CMEs with NASA's Solar Terrestrial Relations Observatory (STEREO) has supplied some perception into their 3-dimensional (three-D) propagation, the mechanisms governing their evolution live. Affecting our magnetosphere with not unusual magnetic discipline strengths of 13 nT and energies of ~1025 J, they might cause telecommunication and Global Positioning System (GPS) errors, strength grid screw-ups, and prolonged radiation risks to astronauts. It is consequently crucial to recognize the forces that decide their evolution, which will better forecast their arrival time and effect on Earth and at some unspecified time in the future of the heliosphere (Liewer et al., 2021; Ravishankar & Michałek, 2019).

1.1.3. Mechanisms for solar-climate connections

Solar radiation, which reaches the Earth, barely changes because of the dynamical characteristics of the Sun. There are lengthy-time period adjustments in solar irradiance that have time intervals of a few years to a long time or centuries. In addition to those adjustments are the quick-term white-noise signals inclusive of each day and month-to-month modifications. Other adjustments are more periodic, just like the Hale sun cycle (Audu & Okeke, 2019; Courtillot et al., 2007). The overall solar irradiance (TSI) amplitude adjustments among maximum and minimum sun Schwabe solar interest cycle, approximately 1 Wm−2. The ensuing forcing on the Earth's floor is round zero.17 Wm−2 (Gray et al., 2010). In a lower back-on-the-envelope calculation, the usage of standard values ends in a trade of zero.08–0.16 K of suggested floor warming. However, a change in TSI is going in hand with a special distribution of the sun energy spectra. The modifications in the ultraviolet (UV) a part of the solar spectrum will especially affect stratospheric ozone, probably leading to a non-linear reaction of the floor climate.

1.1.4. North Atlantic oscillation

The North Atlantic Oscillation (NAO) is the most critical massive-scale climatic oscillation affecting the North Atlantic region. The variability added through the NAO affects many meteorological parameters, inclusive of differences in wind speed and route, air temperature, and rainfall, particularly at some stage in the boreal iciness (Albers & Newman, 2021; Wang & Ting, 2022). The NAO is likewise recognized to affect the ocean by gyre flow, changing warmth content material, salinity, mixed layer depth, sea surface temperature, high-range deep water formation, and sea ice cowl. NAO index has been extensively used to research and calculate the rate of variability of marine ecosystems see **Figure 3**.

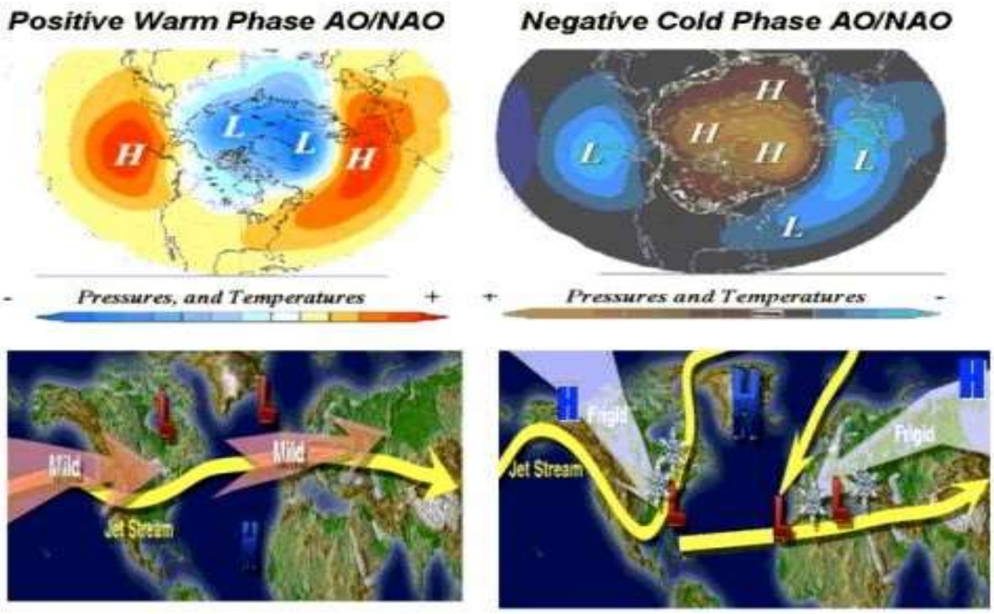


Figure 3: Positive and negative mode of NAO index [Source: newx]

The "backside-up" mechanism, a "pinnacle-down" mechanism related to variations of the solar UV radiation was broadly used to explain the placed NAO-like reaction in the boreal wintry climate. The progressed solar-UV radiation inside the solar-most years increases the air temperature in the tropical top stratosphere with the aid of right now radiative heating and developing ozone manufacturing. This can boost the meridional temperature gradient and exchange the suggested glide. The sun sign ought to propagate downward via interactions with a few of the implied waft and upward planetary waves. Once the sun sign propagates right down to the floor, the AO is extra lively and stronger. Meanwhile, the spatial shape of the NAO indicates a hemispherical structure extending into the stratosphere in the sun-maximum years, whereas it is constrained in the Atlantic zone in the path of the solar-minimal years. The reaction of the NAO to the 11-12 months sun cycle can be amplified with the aid of the terrific feedback from the sea with some years lagged. However, the lagged NAO reaction is absent in some climate simulations, which can be due to inadequate ocean feedback in the climate fashions.

As mentioned previously, the fundamental intention of this work is to research the interrelationships amongst sun spots vicinity and HCMEs with NAO index at the solar 20-second and 23rd cycles, the results have been stated to expose their dependency which therefore can be used to anticipate the behavior of NAO index within the subsequent sun cycles this is used as a hallmark to climatic variability. Solar hobby rises and falls with an 11-12 months cycle that impacts existence on Earth in lots of techniques Shown in Figure four. Since Solar Cycle 21, there may be a weakening fashion in all solar cycles. Increased Solar hobby consists of will growth in the extreme ultraviolet, X-ray emissions excellent varieties of lively particles, and thermonuclear radiation from the Sun that produce dramatic effects in Earth's higher environment (Courtillot et al., 2021). The associated atmospheric heating will grow the temperature and density of the top ecosystem at many spacecraft altitudes and produce drag force on satellites in low Earth orbit can dramatically shorten the orbital lifetime of this treasured property see **Figure 4**.

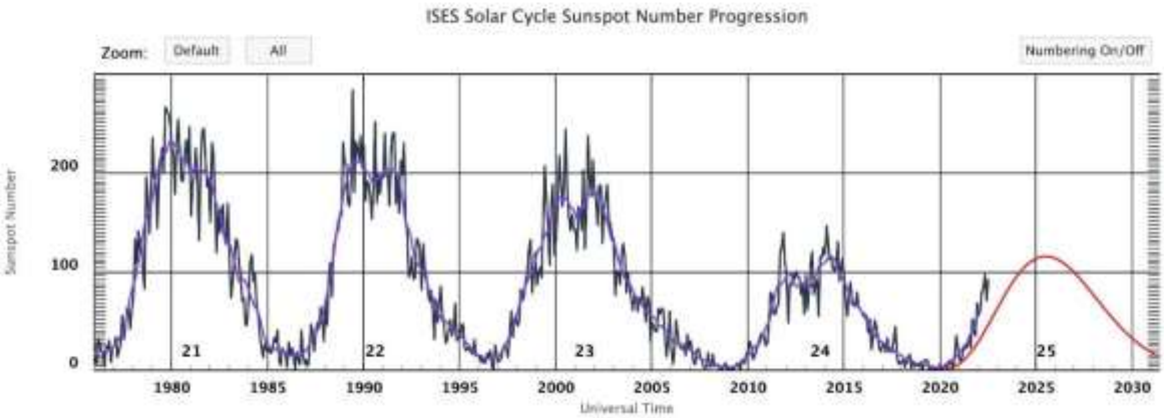


Figure 4: Solar activity cycle and its descending trend of activity [Source: Nasa]

Measures of solar interest may be based on many observable and measurable phenomena. All of them have a not unusual characteristic: they are all varying (at least nearly) in segment or anti-segment with the sunspot numbers. Sunspots are not the handiest capabilities that vary during a sun cycle. There are dramatic adjustments in the chromosphere and corona as well. (David H. Hathaway, 2015)

1.2. Research Gap:

The defined studies problem is a multimodal evaluation of the complicated interaction among solar interest, High-Speed Coronal Mass Ejections (HCME), and the North Atlantic Oscillation (NAO), posing several tremendous problems that require in-intensity examination. The fundamental goal of this research is to recognize the lengthy-time period fluctuations and relationships between the NAO and sun pastime indicators, which include sunspot area and HCME, throughout numerous sun cycles. Although previous research has recommended a few correlations, there's nevertheless a vast have a look at a vacuum of information regarding the sort, consistency, and depth of those institutions over long periods. An extra complete expertise of the interaction between sun pastime and the weather could be achieved with the aid of addressing the essential query of the way fluctuations within the NAO correspond with solar interest indices. Examining the techniques underlying the found connections between sun pastime indices and the NAO presents a parallel trouble. Though there's proof of a connection, our know-how of the ideal bodily mechanisms involved remains missing. To enhance our know-how of climatic variability and create a causal framework for the found relationships, it's miles crucial to get to the bottom of these complexities. To answer troubles regarding how sun variability interprets into NAO changes and, finally, contributes to broader climatic dynamics, they have a look at venture calls for targeted research of the underlying mechanisms.

The research challenge additionally consists of the practical implications of these relationships that have been diagnosed, highlighting the need to compare the predictive ability of HCME and solar activity indicators for destiny climate fluctuations, in particular in phrases of forecasting NAO behavior. This element tackles the critical topic of whether or not sun activity styles may be used to create beneficial indicators for wider weather variability. Closing this gap is crucial for the development of science in addition to for the advent of useful instruments for climate prediction and mitigation which have real-global uses. Another aspect of the research project is temporal dynamics and weather implications, which call for investigating how the found correlations trade throughout one-of-a-kind solar cycle levels and their feasible nearby, nearby, and international outcomes on weather patterns. Gaining know-how of these temporal fluctuations is important for comprehending the long-term consequences of sun-climate interactions and for developing extra sophisticated know-how of the interrelated mechanisms influencing Earth's weather. Lastly, integrating numerous statistics sources—together with sunspot areas, HCME occurrences, and NAO indices—affords a problem in bringing disparate elements of the sun-weather system collectively. For the motive of making a complete photo of lengthy-time period fluctuations and connections, it's miles vital to integrate and examine these numerous facts and resources effectively. By taking into account the connections and synergies among many additives of the solar-weather device, addressing this as a part of the study project would assist in facilitating an extra thorough understanding of climatic variability.

2. METHODOLOGY

In structural equation modeling (SEM), a model is employed to demonstrate the interconnected talents of factors believed to be causally connected. This technique entails latent variables, which are not at once observable, and their presumed causal relationships, depicted in arrow-crammed diagrams. These latent variables connect to determine variables in a dataset through additional causal relationships, with equations used to explicit those connections. The proposed causal structures generate patterns amongst discovered variables, permitting evaluation of information consistency and estimation of theorized results. Moderating variables influence dating dynamics, even as mediating variables elucidate the mechanism between two associated variables. For example, alertness may additionally mediate the hyperlink between instructional achievement and sleep fine. Moderators, changing the route or energy of a courting, consist of factors like intellectual health fame, influencing the affiliation among academic achievement, and sleep nice. The look methodology lacks clarity and has to articulate the specifics of employing SEM to analyze causal relationships, ensuring a significant interpretation of the interconnected variables, the hypothetical theoretical relationship is shown in **Figure 5**.

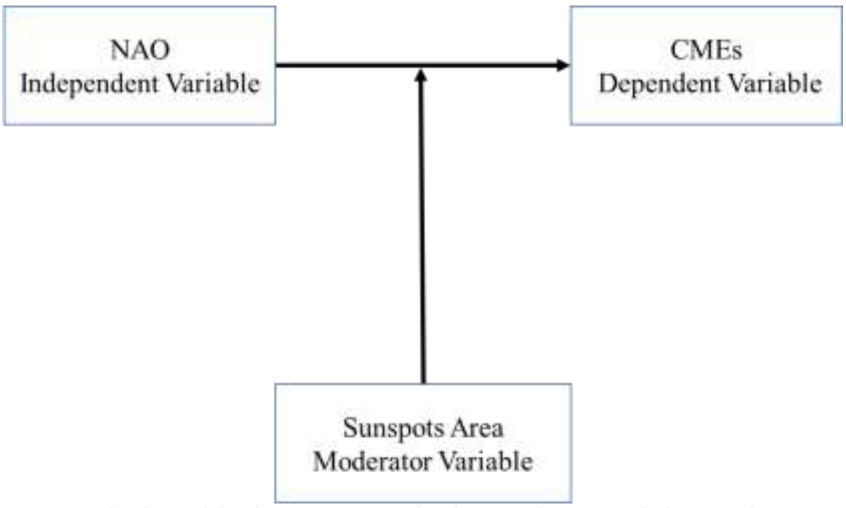


Figure 5: Relationship between an independent and dependent variable

3. Data empirical description and statistical analysis

An Overview of Solar Cycles 22 and 23

The sun's cycles, which come around once every eleven years, represent the dynamic ebb and flow of solar activity that affects Earth's climate. Two of the cycles in this pattern are Solar Cycles 22 (which ran from 1986 to 1996) and 23 (which ran from 1996 to 2008). Variations in sunspots, solar flares, and different sun events take regions all through these cycles, imparting the opportunity to research their feasible results on Earth's weather.

3.1 Solar cycle 22 and 23 comparisons: Sunspots Number & Sunspots Area & NAO

Sunspots Comparative Number:

Sunspots Number

There became a sizeable boom in sunspot pastime in the course of Solar Cycle 22, which peaked approximately in 1989 and turned into suggestive of multiplied sun magnetic interest. The quantity of sunspots peaked, indicating a robust impact on sun irradiance and the opportunity to affect Earth's climate. While there are no longer as many sunspots as in Solar Cycle 22, which peaked around in 2001, it turned into nevertheless a brilliant duration of solar pastime. Examining the variations in sunspot counts across these cycles affords information approximately how the mechanics of the sun's effect on Earth are converting.

North Atlantic Oscillation (NAO):

A possible dating between solar activity and the North Atlantic Oscillation (NAO) was shown via Solar Cycle 22. Regional weather styles are greatly impacted by the North Atlantic Oscillation (NAO), which is defined via variations in air stress over the North Atlantic. Gaining know-how about how Solar Cycle 22 impacted the NAO can help one better apprehend the complicated relationships that exist between solar variability and atmospheric dynamics. Examining the relationship between Solar Cycle 23 and the NAO turns important to envision whether or not such relationships continued, because versions in sun pastime can nonetheless affect atmospheric stream styles, which in turn affect Northern Hemisphere climate occurrences.

A. Solar Cycle 22:

A.1 Sunspots number of cycle 22

Examined in my view for each zone of each 12 months in Solar Cycle 22, the frequency distribution of sunspot numbers gives essential facts on the temporal variation of sun hobby throughout the 11-year time frame. Solar Cycle 22 began in 1986 and resulted in 1996, peaking around in 1989. A thorough understanding of the cyclical nature of solar hobby can be received from the quarterly breakdown of sunspot numbers. Sunspot numbers typically rise and fall in the first and quit years of the cycle, peaking within the center years. An extra-intensity comprehension of the temporal dynamics inside every annual phase may be executed by inspecting quarterly fluctuations in this distribution, which mirrors the typical waxing and waning sample of solar cycles. This type of dissection allows scientists to pinpoint certain instances of multiplied or decreased sun pastime, which provides a radical examination of the sunspot frequency distribution throughout Solar Cycle 22. Frequency distribution of sunspots variety of cycle 22, one after the other for every region in every year of the cycle as shown in **Figure 6**, months January to December as a consequence.

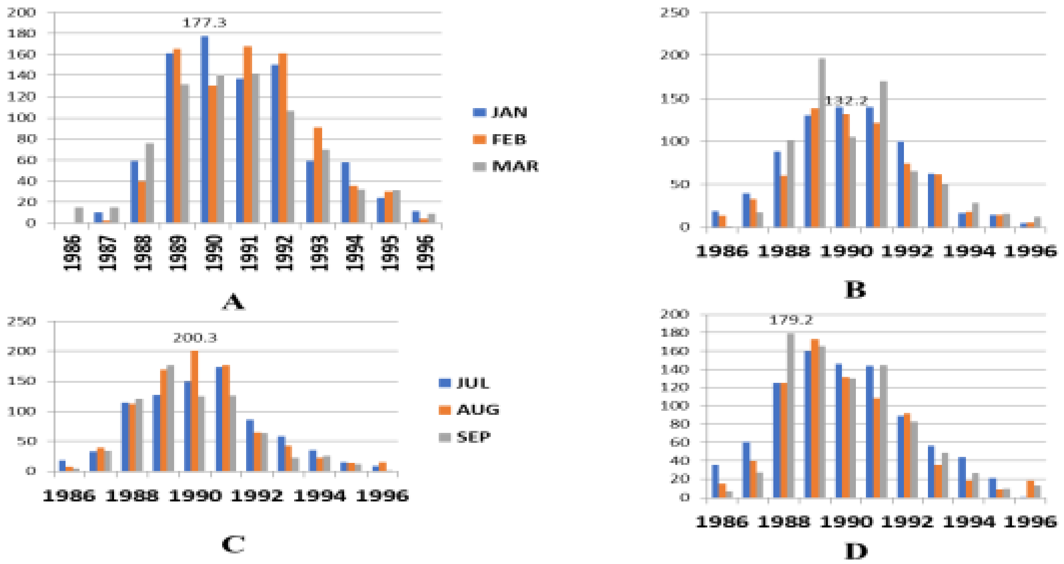


Figure 6: Frequency distribution of sunspots number of cycle 22, separately for each quarter in every year of the cycle.

The above Figure offers an in-depth frequency distribution of sunspot numbers in the course of everything of solar cycle 22. The information is meticulously dissected into quarters, offering a complete view of the sunspot hobby year-round. This granular analysis allows for nuanced information on the cyclical variations in sunspot numbers all through every section of the solar cycle.

A.2 Sunspots area of cycle 22

A full evaluation of the spatial residences of sun interest at some point of the 11-year length from 1986 to 1996 can be acquired by way of searching on the frequency distribution of sunspot regions during Solar Cycle 22, in my view for each area in each 12 months of the cycle. Understanding the dynamics of the solar cycle requires information on sunspot location, a quantitative measure of sun hobby. Researchers are capable of seeing how sunspots place adjustments throughout the path of the sun cycle by way of segmenting the records quarterly for every 12 months inside the cycle. With this first-rate-grained method, it is viable to pinpoint individual quarters wherein versions in sun interest, as shown utilizing the sunspot location, arise. Comprehending the quarterly fluctuations in sunspot vicinity enhances the research of the temporal dynamics in Solar Cycle 22, illuminating the geographic arrangement and value of solar interest at wonderful levels of the cycle. Frequency distribution of sunspots vicinity of cycle 22, one after the other for each zone in every year of the cycle as proven in **Figure 7**.

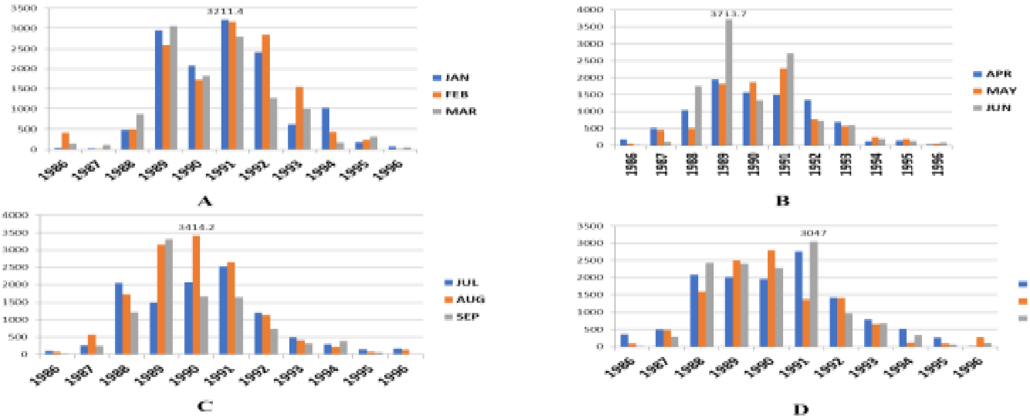


Figure 7: Frequency distribution of sunspots area of cycle 22, separately for each quarter in every year of the cycle.

The above Figure showcases a frequency distribution of sunspot areas for cycle 22, classified through quarters every twelve months of the cycle. This unique breakdown gives a comprehensive exploration of ways sunspot areas range within the course of the solar cycle, offering insights into seasonal and cyclical patterns. Analyzing the distribution of sunspot areas for specific quarters contributes to our knowledge of solar dynamics and aids in deciphering patterns in the solar hobby cycle.

A.3 NAO index of cycle 22

When the frequency distribution of the North Atlantic Oscillation (NAO) index is tested for every region of Solar Cycle 22, in addition to for every 12 months of the cycle, it gives a radical study of the atmospheric variability related to this specific solar duration, which runs from 1986 to 1996. Weather styles and climatic variability are inspired by the NAO index, which describes versions of air stress over the North Atlantic location. Through the evaluation of the quarterly fluctuations, scientists are capable of picking out the seasonal subtleties of NAO dynamics in every year of Solar Cycle 22. By making it less complicated to pinpoint specific quarters in which the NAO index is in a wonderful, horrific, or impartial section, this technique offers intensive know-how of the atmospheric oscillations linked to solar variability at numerous levels of the cycle. Deeper expertise on the connection between solar interest and atmospheric situations in the course of Solar Cycle 22 is made possible using the sort of targeted research. Frequency distribution of the NAO index of cycle 22, separately for each area in every year of the cycle as shown in **Figure 8**.

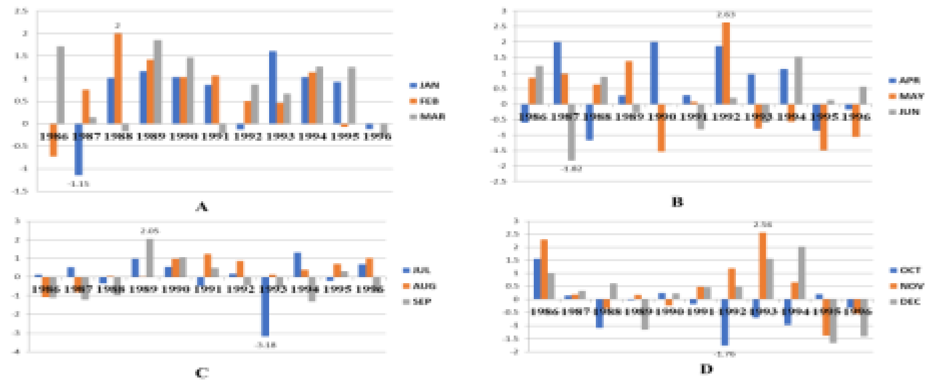


Figure 8: Frequency distribution of NAO index of cycle 22, separately for each quarter in every year of the cycle.

Figure 8 exhibits also a frequency distribution of the North Atlantic Oscillation (NAO) index for cycle 22, classified with the aid of quarters in every year of the cycle. This precise presentation allows for an extensive exam of the manner the NAO index values vary in the direction of the solar cycle, imparting insights into seasonal and cyclical styles. Analyzing the distribution of NAO index values throughout unique quarters complements our records of the complicated interplay among sun pastime and atmospheric dynamics, specifically inside the context of the NAO.

A.4 Daily sunspot number and NAO INDEX of cycle 22

During Solar Cycle 22, which ran from 1986 to 1996, the daily sunspot range and North Atlantic Oscillation (NAO) index provide a rich dataset for analyzing the dynamic interplay among solar interest and atmospheric conditions. The amount and size of sunspots on the solar floor are contemplated within the day-by-day sunspot range, which capabilities as a quantitative indicator of sun interest. Concurrently, the NAO index presents facts on the range of the atmospheric movement patterns by describing the versions in air strain over the North Atlantic. Upon nearer inspection, each day's sunspot range indicates that solar pastime is cyclical throughout the eleven-year sun cycle. The waxing and waning stages of Solar Cycle 22 are represented by way of the peaks and troughs within the sunspot counts, with tremendous everyday modifications. The dynamic person of sun interest, such as the formation and dissolution of individual sunspots in addition to the general fashion of solar magnetic activity, is captured via those everyday oscillations (Figure 8). Daily adjustments in atmospheric strain styles over the North Atlantic region at some stage in Solar Cycle 22 are simultaneously discovered by using the NAO index statistics. The NAO index's high-quality and terrible levels, which represent opposing stress anomalies, are a mirrored image of the atmospheric dynamics linked to solar variability. More exact information on ways the NAO reacts to day-by-day fluctuations in solar pastime may be received utilizing reading these day-by-day versions, which additionally clarifies the quick-time period atmospheric consequences of sun impacts.

Through the status quo of a correlation between the daily NAO index and the sunspot variety, scientists can inspect the immediate and viable not-on-time effects of solar interest on patterns of atmospheric circulation. This thorough observation gives intensive expertise into the complicated interplay between solar cycle variability and atmospheric variability during Solar Cycle 22, making good-sized contributions to our comprehension of everyday sun-climate relationships. R-Squared (R^2 or the coefficient of dedication) is a statistical degree in a regression version that determines the percentage of variance within the structured variable that can be defined by way of the independent variable, Value of R2 statistically tremendous (R2=0.9096) as proven in **Figure 9**.

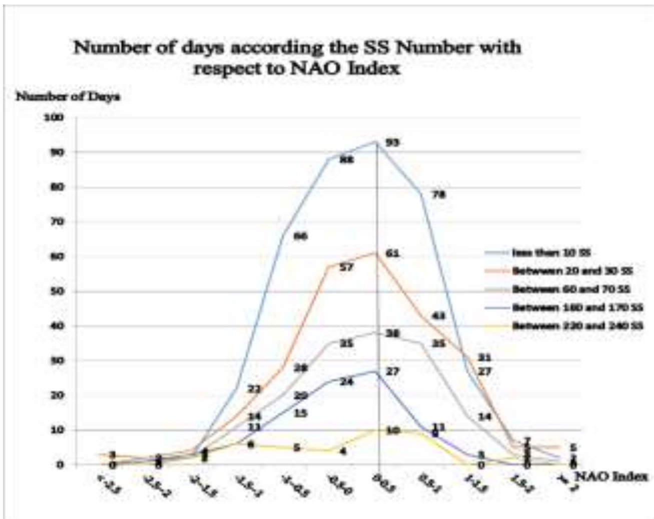


Figure 9: Relation between the Number of Days and the NAO Index.

In addition, **Figure 9** displays a graph illustrating the correlation between the number of days and the North Atlantic Oscillation (NAO) index. This plot presents a visual illustration of ways the NAO index varies over the years, taking into account the exploration of temporal patterns or tendencies. Analyzing the relationship between most of the length in days and the corresponding NAO index values contributes to information on the temporal dynamics of atmospheric changes represented via the NAO, probably revealing patterns or cycles in its behavior.

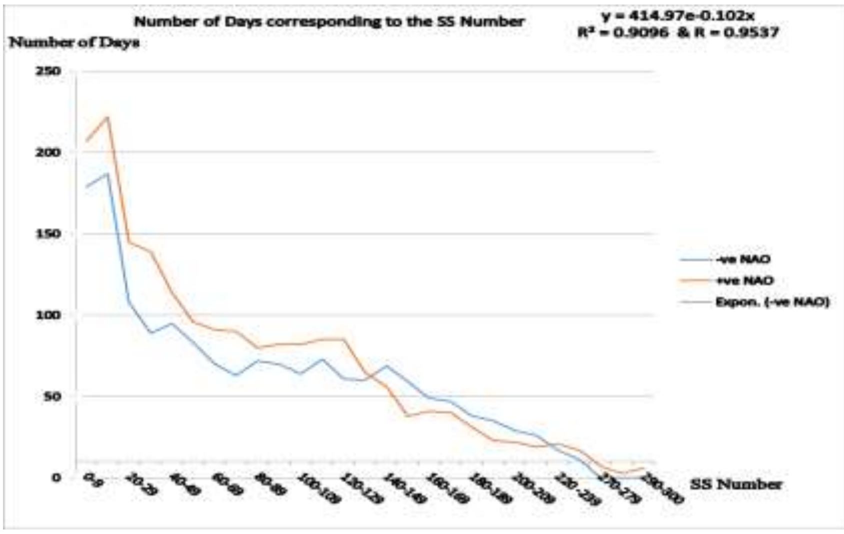


Figure 10: Relation between the Number of Days and the Snapshot Number.

Figure 10 shows a graphical example of the correlation between the number of days and photo numbers. This plot allows for the exploration of temporal patterns and trends within the dataset. By analyzing the connection between the period (in days) and the corresponding picture numbers, the plot offers insights into any temporal variations or cyclic styles captured by the snapshots. Analyzing this form of courting contributes to expertise in the time-structured dynamics represented by the useful resource of the snapshots.

B. Solar cycle 23

B.1 Sunspots number of cycle 23

When the frequency distribution of sunspot numbers at some point of Solar Cycle 23 is examined individually for every quarter in each cycle/year, it offers a complete knowledge of how sun hobby modified over time between 1996 and 2008. Understanding the quarterly fluctuations in sunspot stages permits an extra sophisticated investigation of the cyclical styles in the eleven-year solar cycle. Solar Cycle 23 peaked around in 2001. The frequency distribution normally indicates a clear pattern, and the quarterly breakdown identifies sure tendencies. The solar interest peaks inside the middle years of the cycle, with the first and closing years of the cycle often displaying a growing and losing tendency, respectively. Researchers can achieve a greater unique image of the temporal dynamics of the sun cycle by identifying durations of increased or reduced sun interest inside each year via segmenting the records into quarterly durations. By making it easier to pick out the quarters with the best sunspot activity, this nice-grained look aids in the detection of tendencies and anomalies within Solar Cycle 23. To completely represent the Sun's conduct throughout this specific era, the quarterly frequency distribution is a beneficial tool for taking pictures of the variability of a solar hobby at some point of distinctive components of the sun cycle see **Figure 11**.

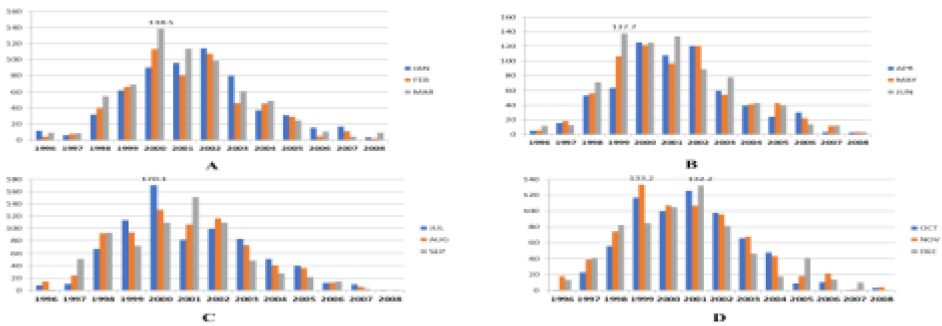


Figure 11: Frequency distribution of sunspots number of cycle 23 separately for each quarter in every year of the cycle.

In **Figure 11** the frequency distribution of sunspot numbers for cycle 23, delineated by way of using quarters in each 12 months of the cycle. This targeted breakdown allows for a complete exam of approaches to sunspot numbers range for the duration of the sun cycle, imparting insights into seasonal and cyclical styles. Analyzing the distribution of sunspot numbers throughout one-of-a-kind quarters complements our know-how of solar dynamics and contributes to deciphering styles inside the sun pastime cycle.

B.2 Sunspots area of cycle 23

A thorough exam of the sunspot area and size over the eleven-year duration of Solar Cycle 23 (1996-2008) may be received by studying the quarterly frequency distribution of the sunspot vicinity. This quantitative metric, which captures the spatial functions of solar interest, shows exceptional developments in every one of the 4 quarters of the year. This breakdown helps to provide an extra-specified view of the dynamic nature of solar activity all through this cycle by allowing the identification of positive intervals characterized by suggested or subdued sunspot regions. The variability in sunspot vicinity is captured by this pleasant-grained look, which makes it possible to discover styles and anomalies within each quarterly segment and offers insightful data approximately the geographical dynamics of Solar Cycle 23 see **Figure 12.**

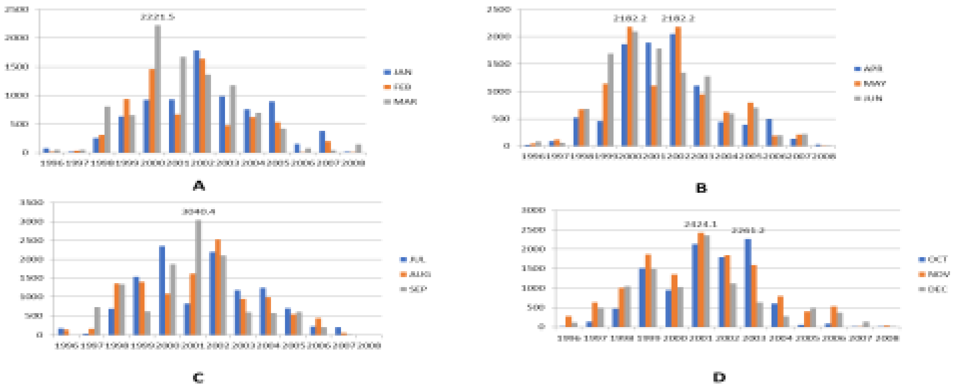


Figure 12: Frequency distribution of sunspots Area of cycle 23 separately for each quarter in every year of the cycle.

This unique breakdown offers a complete assessment of ways sunspot areas vary at some stage within the sun cycle, supplying insights into seasonal and cyclical styles. The assessment of sunspot region distribution during particular quarters enhances our understanding of solar dynamics and contributes to discerning styles in the sun pastime cycle.

B.3 NAO index of cycle 23

By analyzing the frequency distribution of the North Atlantic Oscillation (NAO) index for every region of Solar Cycle 23 independently for every 12 months of the cycle from 1996 to 2008, important information about the atmospheric variability related to this particular solar generation may be acquired. Weather patterns and climatic variability are stimulated with the aid of air stress adjustments over the North Atlantic, as measured via the NAO index. The quarterly cut-up permits an in-depth assessment of the NAO index's annual fluctuations, revealing particular tendencies throughout numerous seasons. Throughout the path of the 4 quarters of the 12 months (see **Figure 13)**, the frequency distribution indicates distinct styles within the high quality, terrible, or impartial stages of the NAO index. Researchers can locate adjustments in styles of air stress, which can be associated with distinct levels of the solar cycle. This quarterly evaluation helps to offer a greater distinctive understanding of the intricate interactions among sun pastime and atmospheric situations throughout Solar Cycle 23, by pinpointing precise instances when the NAO index presents specific atmospheric anomalies. Understanding the quick-term atmospheric outcomes of solar forces all through this 11-12 months cycle requires such distinctive insights that are important.

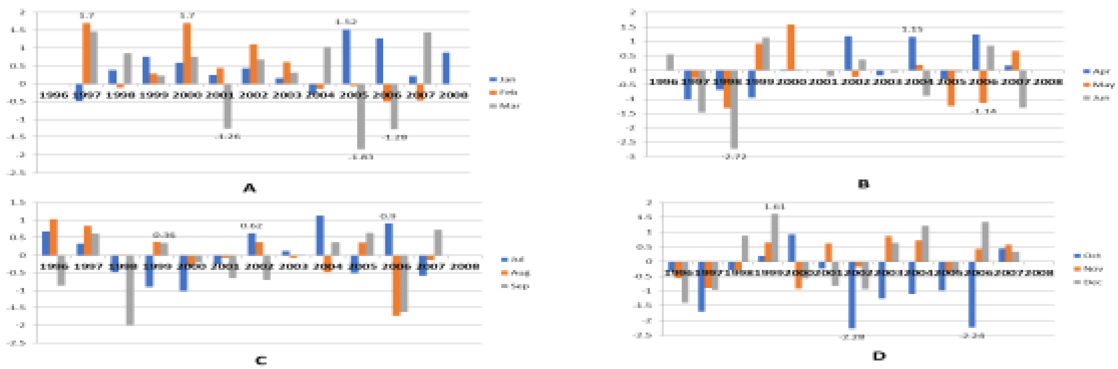


Figure 13: Frequency distribution of NAO index of cycle 23 separately for each quarter in every year of the cycle.

This precise representation allows for a comprehensive exam of the variation in NAO index values over the route of the sun cycle, imparting insights into seasonal and cyclical styles. Such assessment complements our expertise in the hard relationship between solar hobby and atmospheric dynamics, specifically in the context of the NAO.

B.4 Daily sunspot number and NAO INDEX of cycle 23

A comprehensive dataset for comprehending the dynamic interaction among sun hobby and atmospheric situations on a day-by-day basis is furnished by analyzing the day-by-day sunspot variety and North Atlantic

Oscillation (NAO) index for the duration of Solar Cycle 23, which ran from 1996 to 2008. The NAO index describes the variations in air stress over the North Atlantic, at the same time as the everyday sunspot quantity suggests the fluctuating quantities of solar activity. A specified analysis of day-by-day sunspot counts reveals the cyclical patterns present in the solar pastime, illustrating the sunspot counts' steady waxing and waning throughout the path of the sun cycle. Understanding each day's fluctuations in solar magnetic interest is made viable by utilizing the peaks and troughs in the sunspot numbers, which help us realize the Sun's dynamic behavior throughout Solar Cycle 23. According to Figure 13, R^2 indicates how well the data healthy the regression model ($R^2 = 0.996$).

The day-by-day NAO index data additionally makes it feasible to analyze everyday atmospheric stress styles over the North Atlantic location. The NAO index's effective and bad stages, which represent opposing pressure anomalies, are a mirrored image of the daily dynamics of the surroundings related to solar variability. Analyzing those each-day fluctuations offers a detailed view of how the NAO reacts to unexpected variations in sun pastime and sheds mild on the quick-time period atmospheric consequences. By setting up a correlation between each day NAO index and the sunspot-wide variety, scientists may additionally look at the instantaneous and feasible delayed effects of sun hobby on atmospheric movement patterns. This thorough study adds to our expertise of the complicated dating that exists among sun cycle variability and atmospheric variability in the course of Solar Cycle 23, presenting crucial new statistics approximately the quick-time period dynamics of sun-weather interactions (see **Figure 14).**

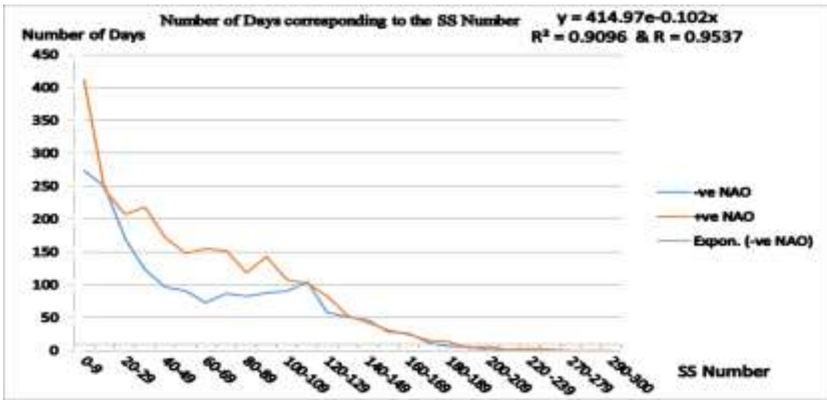


Figure 14: Relation between the Number of Days and the SS Number.

Figure 14 shows a graphical illustration for the correlation between the range of days and sunspot (SS) numbers. This plot offers a seen exploration of the way sunspot activity varies over time, supplying insights into capability dispositions or cyclic styles. Analyzing this dating is important for understanding the temporal dynamics of sunspot hobby and may contribute to unraveling patterns in the sun cycle.

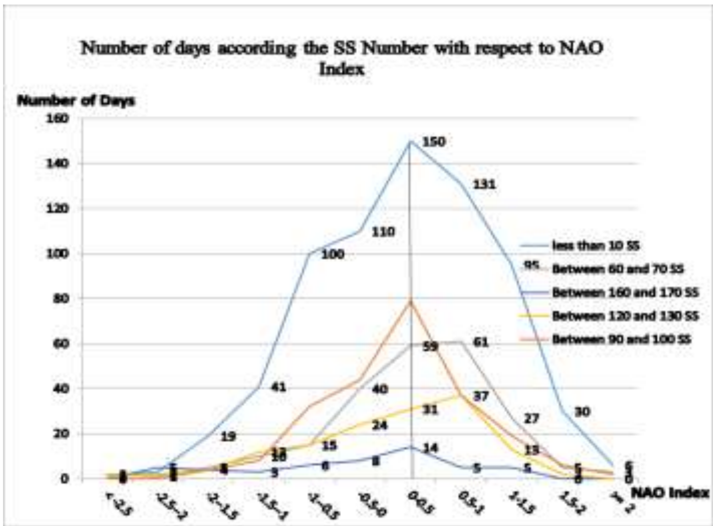


Figure 15: Relation between the Number of Days and the Snapshot Number.

Figure 15 shows a graph depicting the relationship between the number of days and photo numbers. This visual illustration allows for an exam of temporal patterns and traits within the dataset. By correlating the period (in days) with the corresponding snapshot numbers, the plot offers insights into any temporal variations or cyclic styles inside the dataset, helping the interpretation of the time-based dynamics captured by using the snapshots.

3.2 Solar Hallo CME and NAO index for the period April-1969 to March-2015

Studying the correlation between solar Halo Coronal Mass Ejections (HCME) and the North Atlantic Oscillation (NAO) index from April 1969 to March 2015 offers a thorough knowledge of possible relationships between atmospheric variability and solar activity. Space climate and geomagnetic disturbances may be prompted by way of Halo CMEs, which are prominent through their correlation with solar disk middle hobby. Meanwhile, the NAO index is an important gauge of air stress versions during the North Atlantic. Potential relationships can be located by way of analyzing the frequency and houses of Halo CMEs in conjunction with changes inside the NAO index at some stage in this long period. By revealing if periods of extended solar hobby, as recommended by using Halo CMEs, align with specific NAO phases, the studies can shed light on the interaction between sun activities and atmospheric dynamics.
Analyzing this huge dataset makes it less complicated to spot long-time period styles, periodicities, or anomalies within the frequency of Halo CME occurrences and the NAO index's pastime in reaction. Deciphering the tricky relationships between the Sun and Earth's climate gadget calls for information on the temporal dynamics and ability lag outcomes between solar interest and atmospheric reactions. Researchers can locate tendencies and feasible interconnections between Halo CMEs and the NAO index way to this thorough evaluation spanning from April 1969 to March 2015, which advances our information on the relationships between sun radiation and weather over a multi-decadal time frame. Figure 15, Figure 16, and Figure 17 suggest the graph among CME and NAO for that reason.

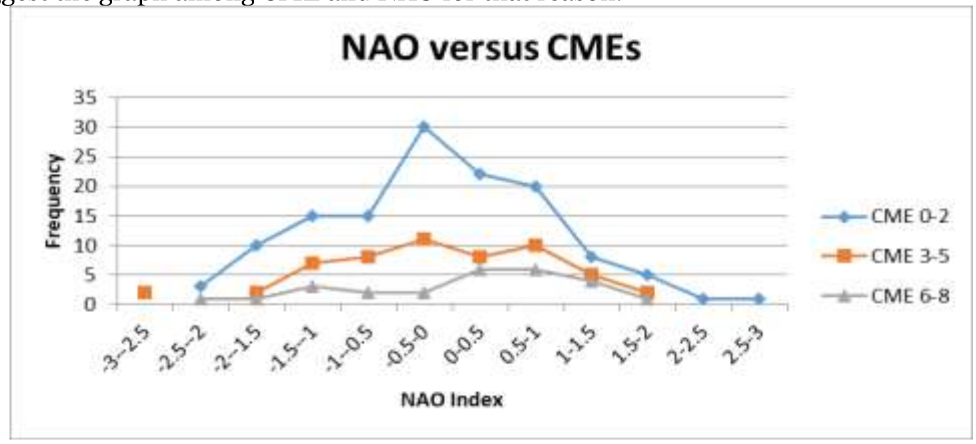


Figure 16: Relation between NAO and CMEs.

Figure 16 gives a graphical instance of the correlation between the North Atlantic Oscillation (NAO) and the occurrence of Coronal Mass Ejections (CMEs). This plot permits a visible exploration of the relationship between atmospheric conditions (as represented by the useful resource of the NAO) and solar activities. Analyzing this connection is critical for discerning potential hyperlinks between area weather phenomena and Earth's atmospheric variability, contributing to greater information on the intricate interaction between sun activity and atmospheric dynamics.

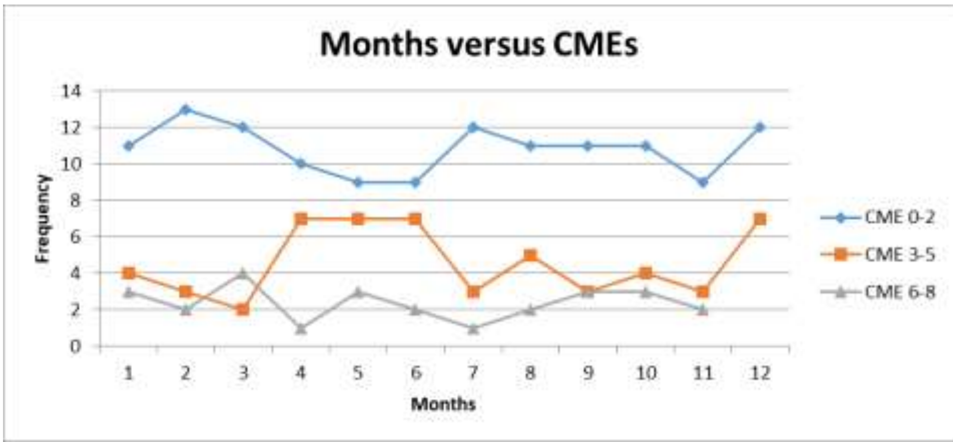


Figure 17: Relation between Month and CMEs.

Figure 17 illustrates a graphical depiction of the correlation between months and the incidence of Coronal Mass Ejections (CMEs). This plot gives a visible illustration of approaches CMEs vary at a few levels in the months, imparting insights into potential seasonal patterns or cyclic tendencies. Analyzing this court is important for knowledge of the temporal distribution of CMEs and their capability effect on place weather dynamics all through specific months of the year.

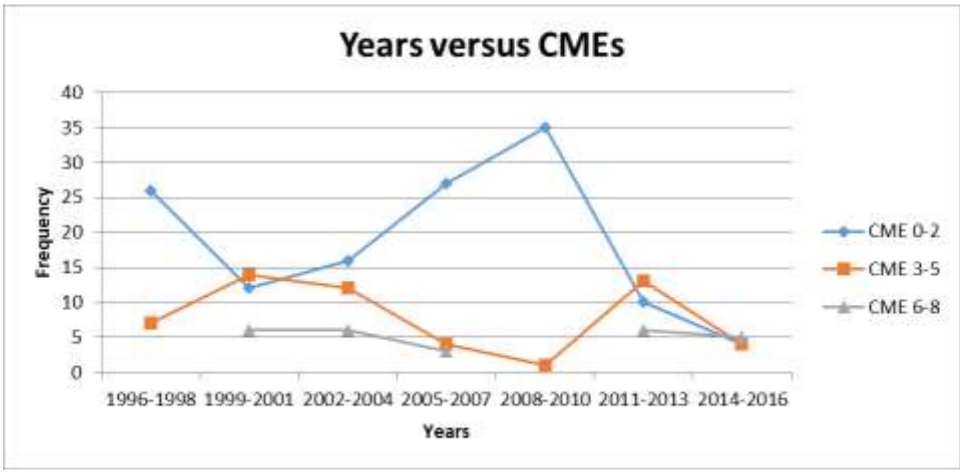


Figure 18: Relation between Years and CMEs

Figure 18 depicts a graphical illustration of the relationship among years and the occurrence of Coronal Mass Ejections (CMEs). The plot offers a seen notion of the temporal distribution of those solar sports, taking into account the statement of traits, patterns, or fluctuations over time. Analyzing this correlation is important for understanding the cyclical nature of CMEs and their ability to affect vicinity climate dynamics throughout tremendous years.

4 RESULTS AND DISCUSSION

4.1 Negative NAO Descriptive Statistics

The North Atlantic Oscillation (NAO) index's descriptive facts can provide a top-level view of its behavior in instances when a terrible segment is present. The jet movement over the North Atlantic shifts southward while NAO situations are bad, which impacts the temperature and climate within the Northern Hemisphere. Measures just like the suggested, trendy deviation, minimal, maximum, and perhaps different pertinent metrics are generally blanketed in descriptive information. During instances of poor phase, those records resource in quantifying the NAO index's variety, valuable tendency, and variability. A wide variety of extensive traits and facts that shed light on the distribution and traits of the North Atlantic Oscillation (NAO) are revealed by using reading fine NAO instances. Positive NAO conditions height in January, making up 10.0% of the pattern, suggesting that this month has a higher frequency of positive NAO situations. On the opposite hand, May has the bottom frequency of nice NAO occasions throughout this era, with a 6.8% incidence. A vast correlation between fine NAO and the winter season is indicated by utilizing the reality that about 30% of high-quality NAO activities are focused inside the iciness zone (DJF) while looking at the seasonal distribution. This result is consistent with the recognized impact of NAO on atmospheric circulate styles all through the winter months over the North Atlantic area.

Additional statistical analysis indicates that an extensive fraction of tremendous NAO values—greater than 65%—are less than or equal to one. This shows that a large percentage of fine NAO activities are characterized by way of fairly mild departures from the climatological default. In a comparable vein, over 95% of high-quality NAO values are much less than or the same as 2, indicating that rather mild high-quality NAO circumstances are common in the pattern. Positive NAO values are determined to comply with a negative exponential curve, which suggests a sure sample of statistical distribution. According to the criteria of a terrible exponential distribution, in which higher values occur less frequently than decreased values, this finding suggests that extremely effective NAO degrees are much less commonplace. Additionally, the facts suggest that advantageous NAO values are about calmly distributed during the month, with January and May displaying the slightest modifications. This uniformity highlights the overall balance of those atmospheric situations in the year with the aid of suggesting a comparatively regular occurrence of fine NAO across numerous months (**Figure 19**).

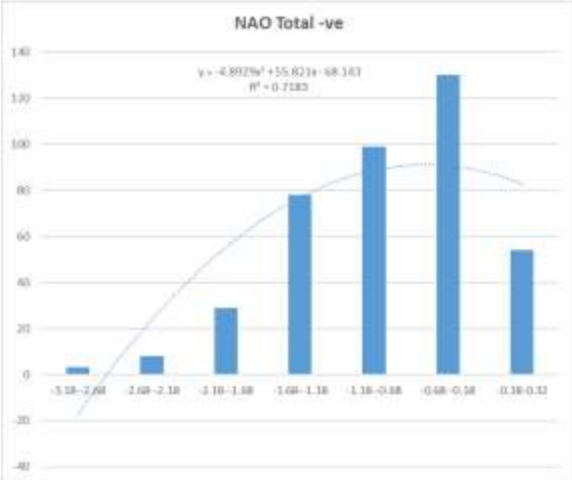


Figure 19: Illustrating the Negative NAO Descriptive Statistics.

Examining seven decades' worth of fantastic North Atlantic Oscillation (NAO) facts and famous precise developments within the functions of this weather phenomenon in various months. When the best positive NAO fee in June is more than 1.6, it indicates a wonderful climatic feature and shows that NAO has a greater effect on atmospheric situations during the summer. On the other hand, November is splendid for having the greatest fantastic NAO values, highlighting the significance of NAOs having an impact on weather patterns in the late fall. Remarkably, March exhibits a top-notch stage of climatic balance, without advantageous NAO values declining beneath 0.08. This highlights the relative lack of severe deviations from the norm at some stage in this particular month and demonstrates the persistence of high-quality NAO conditions in March. However, June has the bottom variety of superb NAO values, indicating that atmospheric conditions for the duration of this early summer time are greatly constrained in their fluctuation.
In addition, in **Table 1**, November shows the widest variety of nice NAO values, indicating a more varied variety of atmospheric variations this month. Throughout the path of the 70-12 months' duration, January's common effective NAO value of 0.67 or better highlights the constant effect of favorable NAO situations throughout the winter, which helps to preserve a stronger atmospheric kingdom right now. Finally, the locating that May has the best average nice NAO similarly helps the spring's climatic relevance, pointing to an extra massive and lengthy-lasting fantastic NAO impact in May all through the multi-decadal dataset. Overall, this thorough evaluation advances our knowledge of the complex interplay between NAO and climatic fluctuations with the aid of imparting insightful facts about the seasonal dynamics and long-term traits of fine NAO values.

Table 1: Shows a month-month statistics for Negative NAO.

	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Max	**1.79**	**2.00**	**1.85**	**2.48**	**2.63**	**1.60**	**1.90**	**1.97**	**2.07**	**1.93**	**3.04**	**2.52**
Min	**0.04**	**0.05**	**0.08**	**0.01**	**0.01**	**0.05**	**0.05**	**0.01**	**0.01**	**0.07**	**0.01**	**0.01**
Range	**1.75**	**1.95**	**1.77**	**2.47**	**2.62**	**1.55**	**1.85**	**1.96**	**2.06**	**1.86**	**3.03**	**2.51**
Average	**0.67**	**0.80**	**0.86**	**0.85**	**0.91**	**0.79**	**0.73**	**0.87**	**0.81**	**0.70**	**0.89**	**0.81**

4.2 Positive NAO Descriptive Statistics

Over a 70-12-month span, the descriptive statistics for nice North Atlantic Oscillation (NAO) conditions display clear tendencies. With a maximum high-quality NAO value of more than 1.6, June stands out as having a mainly sturdy fine NAO impact for the duration of the summertime. November indicates the very best effective NAO values, highlighting the importance of this element in past due fall. March has the highest minimal high-quality NAO cost and no occurrences under zero.08, demonstrating extremely good climate balance. November exhibits the biggest variety, indicating a selection of atmospheric versions, at the same time as June has the lowest variety, indicating a more constant advantageous NAO effect in the summertime. January's climate is solid all through the iciness, as evidenced by its common effective NAO cost of 0.67. Lastly, throughout the direction of the 70-year dataset, May has the best common advantageous NAO values, emphasizing its particular impact on springtime atmospheric situations. Together, this information offers complicated insights into the climatic effect and temporal dynamics of tremendous NAO. When advantageous North Atlantic Oscillation (NAO) events are tested over a certain period, great tendencies within the distribution and homes of this atmospheric phenomenon come to be apparent. Of all of the months in the sample, January has the best frequency of high-quality NAO (10.0%), suggesting that those situations are greater common in the wintry weather. On the other hand, May has the lowest occurrence (6.9%), indicating a lower in the frequency of tremendous NAO events in the late spring. The wintry weather region (DJF) is wherein over 30% of superb NAO activities pay attention, highlighting the connection between nice NAO and winter atmospheric styles. There is a predominance of moderate departures from the climatological norm whilst more than 65% of effective NAO values are less than or equal to at least one. Furthermore, greater than 95% of fantastic NAO readings are less than or equal to 2, suggesting that especially moderate effective NAO circumstances predominate. Extreme values are less unusual than decreased ones, in step with the distribution pattern recommended by the discovered terrible exponential curve in fantastic NAO values. In addition, advantageous NAO ranges are nearly flippantly dispensed at some point of the month, with January and May displaying somewhat distinct values. This consistency suggests that favorable NAO situations arise consistently throughout the year, with subtle versions in the winter and past due spring. When taken as a whole, those results enhance our comprehension of the traits and temporal distribution of positive NAO, leading to a more complete know-how of its climatic importance.

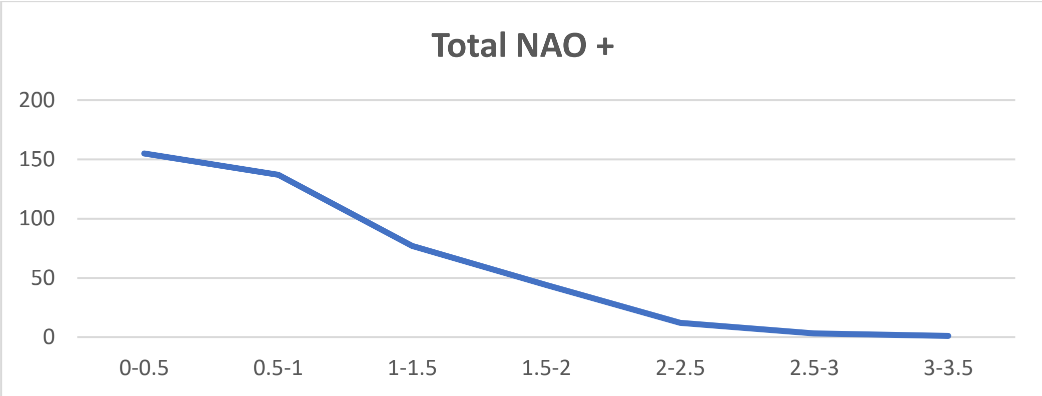


Figure 20: Illustrating the Positive NAO Descriptive Statistics.

Table 2 shows different month-to-month patterns are discovered by analyzing 70 years of advantageous North Atlantic Oscillation (NAO) records. June has the highest positive NAO values (over 1.6), indicating that summertime temperatures are exceedingly influenced by the weather. With the best range and the highest person advantageous NAO values, November stands proud as having a massive impact in overdue autumn. March shows top-notch consistency, without NAO values beneath 0.08. Conversely, June indicates the lowest range, suggesting restricted unpredictability over the summer. January's common high-quality NAO value is frequently at or above zero. Sixty-seven, indicating its good-sized impact during the winter months. With the greatest average fantastic NAO values over the last 70 years, May stands proud of its continual climatic relevance. This work adds to our know-how of the seasonal dynamics and lengthy-time period developments of wonderful NAO and sheds mild on its complicated interplay with atmospheric styles throughout a long time.

Table 2: Shows a month-month statistics for Positive NAO.

	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Max	**1.79**	**2.00**	**1.85**	**2.48**	**2.63**	**1.60**	**1.90**	**1.97**	**2.07**	**1.93**	**3.04**	**2.52**
Min	**0.04**	**0.05**	**0.08**	**0.01**	**0.01**	**0.05**	**0.05**	**0.01**	**0.01**	**0.07**	**0.01**	**0.01**
Range	**1.75**	**1.95**	**1.77**	**2.47**	**2.62**	**1.55**	**1.85**	**1.96**	**2.06**	**1.86**	**3.03**	**2.51**
Average	**0.67**	**0.80**	**0.86**	**0.85**	**0.91**	**0.79**	**0.73**	**0.87**	**0.81**	**0.70**	**0.89**	**0.81**

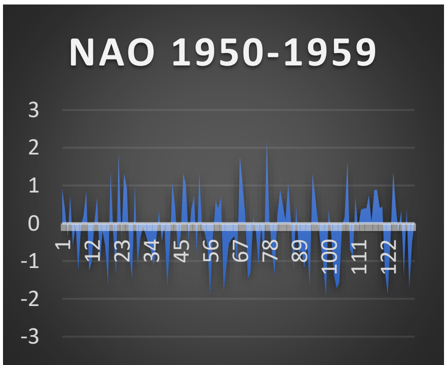
4.3 Ten Years Analysis

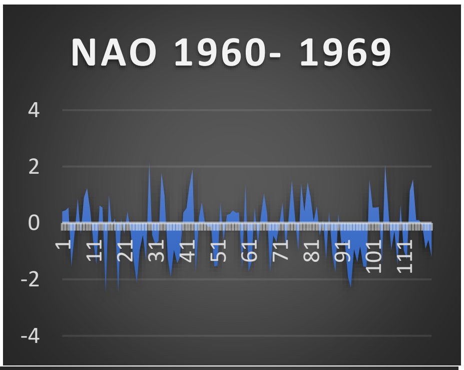
The North Atlantic Oscillation (NAO) showed in **Figure 21** significant extremes in the 50th year of the dataset, with the minimum falling to -1.96 in March 1958 and the highest reaching 2.21 in May 1956. These extremes display the dynamic person of NAO patterns by reflecting extensive atmospheric shifts at some point in this time. The year's prolonged impact of atmospheric conditions related to NAO is suggested by the poor common NAO of -0.14, which suggests a predominance of a terrible section. The large range of 4.17 highlights the complexity of climatic elements influencing the North Atlantic Oscillation in the course of this particular period, as well as the volatility and fluctuation in NAO values at some stage in the path of the 50th 12 months. The North Atlantic Oscillation (NAO) confirmed giant extremes inside the sixtieth year of the dataset, which become indicative of the dynamic nature of climate styles at that point. The highest NAO was 2.16 in May 1963, indicating a strong effective segment and the lowest was -2.47 in March 1962, indicating a strong terrible segment. Interestingly, this year's poor average NAO of -0.23 is at the bottom of the document, indicating a standard trend closer to a terrible NAO country. The huge variety of 4.63 highlights the extensive variant in NAO values over the route of the sixtieth 12 months, highlighting the complex and dynamic interaction of climatic elements influencing the North Atlantic Oscillation all through this particular duration. **Table 3** shows the 10-year analysis. The North Atlantic Oscillation (NAO) verified incredible extremes inside the 70th year of the dataset, highlighting the dynamic and sizable individual atmospheric patterns at some stage in this time. The finest NAO value in the course of the 70-year dataset was reached in November 1978, when the most NAO soared at a wonderful 3.04. On the other hand, February 1978 noticed a minimal NAO of -2.20, indicating a tremendous bad phase. Notwithstanding the extremes, the year's common NAO becomes high quality at 0.06, indicating a popular trend closer to favorable NAO conditions. The huge variety of 5.24 highlights the huge variations in NAO values over the direction of the seventieth year, emphasizing the problematic relationships and climatic phenomena that have formed the North Atlantic Oscillation in the course of this particular length.

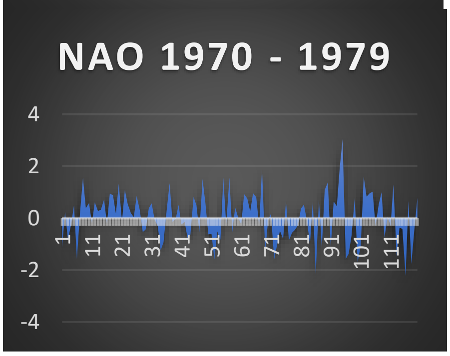
Table 3: Shows the 10-year Analysis.

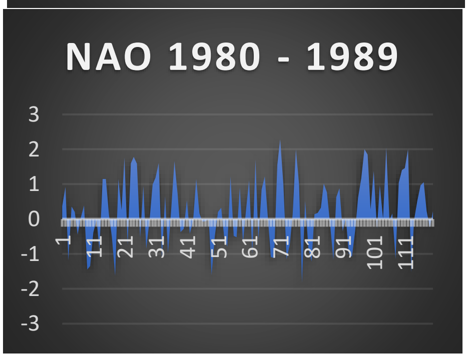
	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019
Max	**2.21**	**2.16**	**3.04**	**2.29**	**2.63**	**1.68**	**2.52**
Min	**-1.96**	**-2.47**	**-2.24**	**-1.82**	**-3.18**	**-2.28**	**-3.18**
Range	**4.17**	**4.63**	**5.28**	**4.11**	**5.81**	**3.96**	**5.7**
Average	**-0.14**	**-0.23**	**0.06**	**0.12**	**0.17**	**-0.05**	**0.09**

The dataset's 80th year shows that the North Atlantic Oscillation (NAO) is still characterized by way of widespread extremes, which is indicative of the dynamic nature of climate styles at some stage in this unique period. While the bottom NAO fell to -2.24 in August 1980, indicating a large poor section, the maximum NAO reached 2.29 in November 1986, suggesting a considerable tremendous segment. Interestingly, the year's nice average NAO of 0.12 points to a popular trend toward favorable NAO circumstances. The extensive variety of 4.53 highlights the huge variation in NAO values during the route of the 80th year, indicating the complicated interaction of climatic elements influencing the North Atlantic Oscillation in the course of this period.
The North Atlantic Oscillation (NAO) displayed huge extremes inside the 90th 12 months of the dataset, indicating a time of extraordinary atmospheric variability. In May 1992, the most NAO skyrocketed to 2.63, signifying a widespread effective section. On the other hand, the minimum NAO fell to -3.18 in July 1992, indicating the bottom NAO value at some point of the 70-12 months' dataset and a unique and robust negative segment. The year's advantageous average NAO changed into an impressive 0.17, the very best value in the past 70 years, indicating a widespread trend towards favorable NAO occasions.









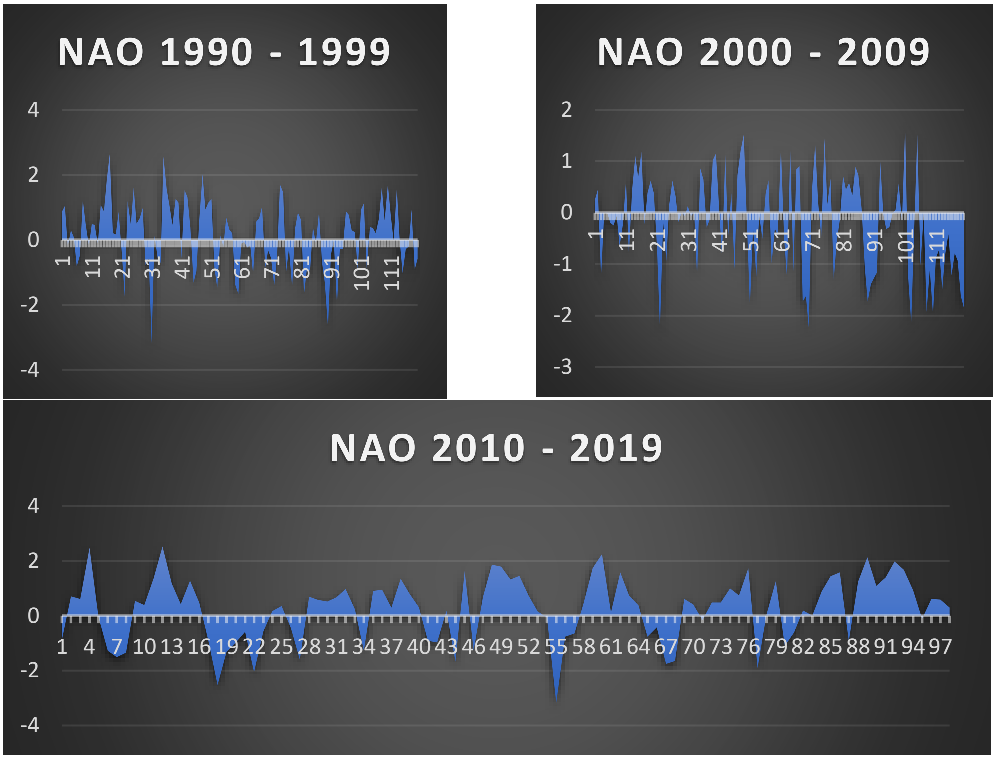


Figure 21: NAO distribution graphs per ten tears.

The wide range of 5.81 highlights the splendid range in NAO values over the path of the 90th year and the intricate climatic dynamics that formed the North Atlantic Oscillation at some stage in this specific period. During the primary decade of the brand-new millennium or the primary decline, the atmospheric patterns of the North Atlantic Oscillation, or NAO, endured to reveal huge fluctuations. In February 2000, the maximum NAO was 1.70, indicating a positive phase at that time. In contrast, a clear negative phase was seen in October 2002 when the minimum NAO fell to -2.28. The duration's negative common NAO of -0.05 suggests a propensity in the direction of generally terrible NAO occasions. Furthermore, the range of three. Ninety-eight is splendid as the lowest range inside the first decay, highlighting an enormously restrained variability in NAO values over this specific period. The aforementioned data spotlight the North Atlantic Oscillation's dynamic characteristics and its susceptibility to weather factors in the early years of the twenty-first century.

During the second decade of the brand-new millennium or the second one decay, there have been terrific fluctuations in atmospheric patterns related to the North Atlantic Oscillation (NAO). December 2011 saw the finest NAO of 2.50 two, suggesting a widespread advantageous section at that point. On the other hand, the minimum NAO fell to -3.18 in July 2015, indicating the lowest NAO value during the examined period and a clear negative phase. The positive average NAO of 0.09 for this time indicates a general tendency towards positive NAO conditions, even with the extremes. Additionally, the range of 5.7 stands out, reflecting a considerable variability in NAO values throughout the 2nd decay. The aforementioned data highlight the North Atlantic Oscillation's dynamic characteristics and its susceptibility to climate factors in the latter part of the 21st century.

The North Atlantic Oscillation (NAO) showed significant extremes and fluctuations in its properties across the seven decades under study. In 1978, the 70th year, the highest NAO was 3.04, indicating a notable positive phase. By contrast, the minimum NAO happened after two decadal cycles, with significant negative phases during the 90th year in 1993 and again in 2015. It dropped to -3.18 during that time. A range of NAO tendencies can be shown by comparing the averages throughout the seven decadal cycles. The 60th 12 months had the bottom average (-0.23), which shows that there had been terrible NAO situations in impact on the time. On the opposite hand, the 90th year saw the highest average of 0.17, indicating a tendency closer to favorable NAO situations. In addition, there has been a version inside the range of NAO values each decadal cycle; the bottom range of 3.96 passed off within the first ten years of the current millennium, suggesting alternatively confined fluctuation. On the other hand, the 90th year saw the greatest variety of 5.81, indicating high-quality versions in NAO values at this unique time. Together, those effects highlight the North Atlantic Oscillation's dynamic and sundry developments over a long time, advancing our statistics of its prolonged-term weather tendencies.

5 CONCLUSION

Reliable and big research on the correlation between solar hobby markers and the North Atlantic Oscillation (NAO) hinges on facts accessibility, consistency, and extraordinary. They take a look at establishing a strong hyperlink between the Sunspots Area and the NAO Index for Solar Cycles 22 and 23, underlining the interconnectedness of solar dynamics and atmospheric variability. The sun cycle moreover famous a noteworthy correlation with Coronal Mass Ejections (CMEs), emphasizing the synchronization of solar events with area weather. The NAO Index, critical for statistics of wintry climate atmospheric changes, appreciably influences weather patterns in excessive latitudes through stress differentials. Positive NAO conditions coincide with the reducing section of the sunspot cycle, aligning with heightened geomagnetic interest, as supported by thru manner of climatic statistics. This connection has cascading outcomes, notably influencing the intensification of wintry weather storms over the Atlantic. The Western Mediterranean studies distinct local impacts, obtrusive in flood occurrences synchronized with NAO stages. These findings underscore the wider implications of sun interest on nearby weather styles, especially in the course of transitions within the dominant NAO section.

References

1. Albers, J. R., & Newman, M. (2021). Subseasonal predictability of the North Atlantic Oscillation. Environmental Research Letters. https://doi.org/10.1088/1748-9326/abe781
2. Arakawa, M., Yasui, M., & Shimaki, Y. R. (2014). High-velocity impact phenomena in the solar system related to the origin and evolution of planets. Review of High Pressure Science and Technology/Koatsuryoku No Kagaku To Gijutsu. https://doi.org/10.4131/jshpreview.24.13
3. Audu, M. O., & Okeke, F. N. (2019). Investigation of possible connections between solar activity and climate change in Nigeria. SN Applied Sciences. https://doi.org/10.1007/s42452-019-0160-x
4. Baumann, I., & Solanki, S. K. (2005). On the size distribution of sunspot groups in the Greenwich sunspot record 1874-1976. Astronomy and Astrophysics. https://doi.org/10.1051/0004-6361:20053415
5. Bellucci, E., Bitocchi, E., Rau, D., Nanni, L., Ferradini, N., Giardini, A., Rodriguez, M., Attene, G., & Papa, R. (2013). Population structure of barley landrace populations and gene-flow with modern varieties. PLoS ONE. https://doi.org/10.1371/journal.pone.0083891
6. Çakmak, H. (2014). A digital method to calculate the true areas of sunspot groups. Experimental Astronomy. https://doi.org/10.1007/s10686-014-9381-6
7. Chatzistergos, T., Ermolli, I., Krivova, N. A., Barata, T., Carvalho, S., & Malherbe, J. M. (2022). Scrutinising the relationship between plage areas and sunspot areas and numbers. Astronomy and Astrophysics. https://doi.org/10.1051/0004-6361/202244913
8. Chiodo, G., Oehrlein, J., Polvani, L. M., Fyfe, J. C., & Smith, A. K. (2019). Insignificant influence of the 11-year solar cycle on the North Atlantic Oscillation. Nature Geoscience. https://doi.org/10.1038/s41561-018-0293-3
9. Courtillot, V., Gallet, Y., Le Mouël, J. L., Fluteau, F., & Genevey, A. (2007). Are there connections between the Earth's magnetic field and climate? Earth and Planetary Science Letters. https://doi.org/10.1016/j.epsl.2006.10.032
10. Courtillot, V., Lopes, F., & Le Mouël, J. L. (2021). On the Prediction of Solar Cycles. Solar Physics. https://doi.org/10.1007/s11207-020-01760-7
11. Drews, A., Huo, W., Matthes, K., Kodera, K., & Kruschke, T. (2022). The Sun's role in decadal climate predictability in the North Atlantic. Atmospheric Chemistry and Physics. https://doi.org/10.5194/acp-22-7893-2022
12. Friis-Christensen, E., & Svensmark, H. (1997). What do we really know about the sun-climate connection? Advances in Space Research. https://doi.org/10.1016/S0273-1177(97)00499-7
13. Hathaway, D. H. (2015). The solar cycle. Living Reviews in Solar Physics. https://doi.org/10.1007/lrsp-2015-4
14. Hurrell, J. W., Hoerling, M. P., & Folland, C. K. (2002). Climatic variability over the North Atlantic. International Geophysics. https://doi.org/10.1016/S0074-6142(02)80163-2
15. Li, Q., Wan, M., Zeng, S. G., Zheng, S., & Deng, L. H. (2021). Predicting the 25th solar cycle using deep learning methods based on sunspot area data. Research in Astronomy and Astrophysics. https://doi.org/10.1088/1674-4527/21/7/184
16. Liewer, P. C., Qiu, J., Vourlidas, A., Hall, J. R., & Penteado, P. (2021). Evolution of a streamer-blowout CME as observed by imagers on Parker Solar Probe and the Solar Terrestrial Relations Observatory. Astronomy and Astrophysics. https://doi.org/10.1051/0004-6361/202039641
17. Lin, C. H., & Chen, J. (2022). Drag Force on Coronal Mass Ejections (CMEs). Journal of Geophysical Research: Space Physics. https://doi.org/10.1029/2020JA028744
18. Mandal, S., Krivova, N. A., Cameron, R., & Solanki, S. K. (2021). On the size distribution of spots within sunspot groups. Astronomy and Astrophysics. https://doi.org/10.1051/0004-6361/202140621
19. Ogurtsov, M., Helama, S., Jalkanen, R., Jungner, H., Lindholm, M., & Veretenenko, S. (2022). Solar-type periodicities in the climate variability of Northern Fennoscandia during the last three centuries: Real influence of solar activity or natural instability in the climate system. Holocene.

https://doi.org/10.1177/09596836211060487
20. Paeth, H., Hense, A., Glowienka-Hense, R., Voss, R., & Cubasch, U. (1999). The North Atlantic Oscillation as an indicator for greenhouse-gas induced regional climate change. Climate Dynamics. https://doi.org/10.1007/s003820050324
21. Petrovay, K. (2020). Solar cycle prediction. In Living Reviews in Solar Physics. https://doi.org/10.1007/s41116-020-0022-z
22. Ravishankar, A., & Michałek, G. (2019). Estimation of Arrival Time of Coronal Mass Ejections in the Vicinity of the Earth Using SOlar and Heliospheric Observatory and Solar TErrestrial RElations Observatory Observations. Solar Physics. https://doi.org/10.1007/s11207-019-1470-2
23. Shen, F., Shen, C., Xu, M., Liu, Y., Feng, X., & Wang, Y. (2022). Propagation characteristics of coronal mass ejections (CMEs) in the corona and interplanetary space. In Reviews of Modern Plasma Physics. https://doi.org/10.1007/s41614-022-00069-1
24. Trouet, V., Scourse, J. D., & Raible, C. C. (2012). North Atlantic storminess and Atlantic Meridional Overturning Circulation during the last Millennium: Reconciling contradictory proxy records of NAO variability. Global and Planetary Change. https://doi.org/10.1016/j.gloplacha.2011.10.003
25. Wang, L., & Ting, M. (2022). Stratosphere-Troposphere Coupling Leading to Extended Seasonal Predictability of Summer North Atlantic Oscillation and Boreal Climate. In Geophysical Research Letters. https://doi.org/10.1029/2021GL096362
26. Woods, T. N., Harder, J. W., Kopp, G., & Snow, M. (2022). Solar-Cycle Variability Results from the Solar Radiation and Climate Experiment (SORCE) Mission. Solar Physics. https://doi.org/10.1007/s11207-022-01980-z