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RESEARCH ARTICLE

Possible Influence of Solar Activity on Lightning Occurrence: A Preliminary Study Over Nepal

Lukesh Mali[1*], Prem Raj Dhungel[1, 2], Shriram Sharma[2], Rojin Shrestha[3]

[1]Department of Physics, GoldenGate International College, Tribhuvan University, Kathmandu, Nepal

[2]Department of Physics, Amrit Science College, Tribhuvan University, Kathmandu, Nepal

[3]Department of Engineering, Pulchowk Engineering Campus, Tribhuvan University ,Kathmandu, Nepal

[*]E-mail: lukeshmali47@gmail.com

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Highlights

- This study delves into a relatively underexplored domain: the relationship between solar activity specifically solar sunspots and F10.7 indices, as well as solar wind speed, on the occurrence of lightning events.
- The study utilizes a rich dataset spanning from 1998 to 2008, capturing an extensive period of solar activity during Solar Cycle 23.
- We observed that the correlation between solar parameters and the lightning occurrence over Nepal are found to vary at different time period from insignificant correlation to moderate correlation.
- Further exploration is needed to shed more light to interpret the relationship between solar activity and the lightning occurrence in Nepal.

Abstract

One of the fundamental mysteries of lightning is its initiation mechanism. Many aspects of lightning phenomenon are well known; however, the exact processes that initiate lightning discharge are not fully understood. This study delves into a relatively underexplored domain: the relationship between solar activity specifically solar sunspots and F10.7 indices, as well as solar wind speed, on the occurrence of lightning events. The study utilizes a rich dataset spanning from 1998 to 2008, capturing an extensive period of solar activity during Solar Cycle 23. Multiple correlation analyses were conducted, comparing solar activity parameters with lightning occurrence. Lightning data was sourced from the Lightning Imaging Sensor (LIS) whereas Sunspot data was obtained from the Solar Influences Data Analysis Center (SIDC) and F10.7 as well as Solar wind data was obtained from the OMNI dataset. From this preliminary study, we observed that the correlation between solar parameters and the lightning occurrence over Nepal are found to vary at different time period from insignificant correlation to moderate correlation. Hence, further exploration is needed to shed more light to interpret the relationship between solar activity and the lightning occurrence in Nepal.

Keywords: Sunspot, Solar wind, F10.7 index, Lightning, discharge

[*]Corresponding author

Introduction

Introduction to Lightning

The mystery surrounding lightning has fascinated scientists and researchers for centuries. Lightning is a natural electrical discharge phenomenon which is a complex and rapid electrical discharge within the Earth's atmosphere, typically accompanied by a brilliant flash of light and a distinct thunderclap.

Mechanism of Lightning Process

Lightning is a spectacular natural phenomenon that occurs during thunderstorms. It begins when there are strong updrafts and downdrafts within a thundercloud. These turbulent air currents cause tiny ice and water particles in the cloud to collide and rub against each other. This rubbing creates a separation of electrical charges, with positively charged particles gathering at the top of the cloud and negatively charged particles congregating at the bottom[1].

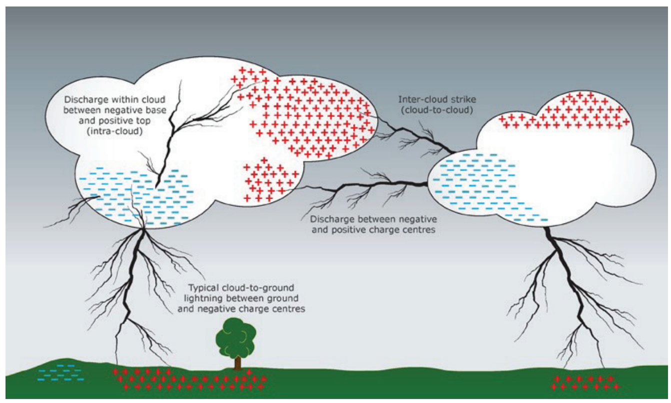

Fig. 1. The charge structure of two simple isolated thunderclouds and some of the locations where the lightning can occur. (Source: https://www.sciencelearn.org.nz)

As this charge separation intensifies, it creates an electric field within the cloud. When this electric field becomes strong enough, it overcomes the insulating properties of the air and causes a sudden discharge of electricity. This discharge is what we see as a lightning bolt. It's essentially a rapid flow of electrons moving from the negatively charged base of the cloud to the positively charged ground or another part of the cloud. The lightning bolt is incredibly hot, reaching temperatures hotter than the surface of the sun. This intense heat causes the air around it to rapidly expand, creating shockwaves we perceive as thunder.

Introduction to Solar Activity

The Sun, our closest star, is a dynamic celestial body that undergoes continuous and complex processes collectively known as solar activity. These processes manifest as various observable phenomena, each contributing to the ever-changing state of the Sun. Understanding and monitoring these solar activities are not only essential for astrophysical research but also have important implications for Earth and space-based technologies, including our understanding of space weather. One of the most recognizable features of solar activity is the presence of sunspot, temporary dark patches on the Sun's surface caused by intense magnetic activity. These sunspots are cooler and less luminous than their surrounding regions due to the magnetic fields inhibiting convection. The number and distribution of sunspots vary in a cyclic pattern known as the solar cycle, which typically spans approximately 11 years. The study of sunspots and their behavior provides insights into the Sun's magnetic dynamo and its influence on the broader solar activity [2].

The Sun constantly emits a stream of charged particles, known as the solar wind, into space. Composed primarily of electrons and protons, the solar wind carries the Sun's magnetic field with it, shaping the environment of the solar system. Solar wind interactions with the Earth's magnetic field are responsible for phenomena such as the Northern and Southern Lights (auroras) and can also impact satellite communications and power grids. Monitoring the solar wind is vital for space weather forecasting and understanding its impact on our technological infrastructure.

F10.7, also known as the 10.7 cm radio flux, is a measure of the Sun's radio emission at a wavelength of 10.7 centimeters. This parameter serves as a proxy for the Sun's ultraviolet and X-ray emissions, which vary with solar activity. F10.7 is a valuable tool for monitoring long-term solar variability and its influence on Earth's ionosphere and atmospheric conditions.

In addition to sunspots, the solar wind, and F10.7, there are various other parameters used to quantify different aspects of solar activity. These include the solar flux at different radio frequencies, solar flares, and coronal mass ejections (CMEs), among others. Each of these parameters provides a unique perspective on the Sun's behavior and its influence on space weather and terrestrial systems.

Possible relation between Solar activity and Lightning

The initiation of lightning remains a mysterious and fascinating phenomenon. Previously it was presumed that there may be some role of cosmic ray in the lightening discharge. However, of late, Scientists have attempted to understand it by exploring possible connections with solar activity and mostly with sunspot [3]. Fritz (1878) found non-significant results when examining the relationship between sunspot activity and lightning occurrence [4]. Brooks (1934) analyzed data from various locations, revealing significant variations in the relationship between sunspots and thunderstorm activity. Stringfellow (1974), found a correlation between sunspot number and day on which thunder was heard ('thunder days') in the UK [5]. Markson (1981) explored the positive correlation between galactic cosmic ray (GCR) flux and ionosphere electric potential [6]. Researchers have proposed mechanisms by which solar activity may influence terrestrial lightning frequencies, including modulation of solar irradiance and GCR flux. However, the mystery remains unveiled. This paper is the first attempt in Nepal in which the relation of solar activity in lightning occurrence is tried to explore using the data of lighting occurrence of Nepal. The findings of this study show varying degree of correlation between them in different time periods.

Methodology

This study is a preliminary study of investigating potential connections between solar activity and the occurrence of lightning events in Nepal. By delving into phenomena such as sunspots, F10.7 radiation, and solar wind speed, the study aims to find quantitative correlations that possibly may find relationship between solar activity and terrestrial lightning. The statistical approach of measuring Pearson's Coefficient is used to find the relation between the lightning occurrences with the solar activity parameters.

Methods and Methodology

The methodology employed for analyzing the relationship between solar activity parameters, including sunspot numbers, F10.7 radiation, and solar wind speed, and lightning events is outlined.

Data Source: The data sources utilized for this study comprise lightning data from LIE, sunspot data from SILSO, F10.7 data, and solar wind speed data was retrieved from OMNI data frame.

Data Collection: Data was gathered from these sources and organized based on Timestamp values, resulting in a dataset covering the period from January 1, 1998, to September 2008. The selection of this time frame mostly overlaps Solar Cycle 23. However, to account for the limited availability of lightning data, the analysis was constrained to this timeframe and also the hourly data of lightning events is a summed up to get the daily value of lightning occurrence.

Correlation Analysis: Initially, an examination of the entire time series was conducted, revealing a non-significant correlation between solar activity and lightning. To gain more meaningful insights, the data was segmented into shorter time periods of days corresponding to lightning data availability. Subsequently, Pearson's correlation coefficient (R value) was computed to quantitatively assess the strength and direction of the relationship.

Data Smoothing: A rolling mean with a window size of 4 was utilized to reduce noise and seasonality of raw data.

Software and Tools: All data preprocessing, correlation calculation and visualization were executed using the Python programming language.

This methodological approach allowed for a systematic investigation of the relationship between solar activity and lightning occurrence, effectively addressing the challenges posed by the intermittent nature of lightning occurrences throughout the year.

Result and Discussion

Initially, an analysis of the entire time series data revealed non-significant correlations between lightning events (Events) and the three solar activity parameters: sunspot numbers (Sunspot), F10.7, and solar wind speed (Solar wind). This lack of significant correlation prompted a more detailed investigation, considering the intermittent nature of lightning occurrences. The whole time series under study is divided into 38 smaller time sections.

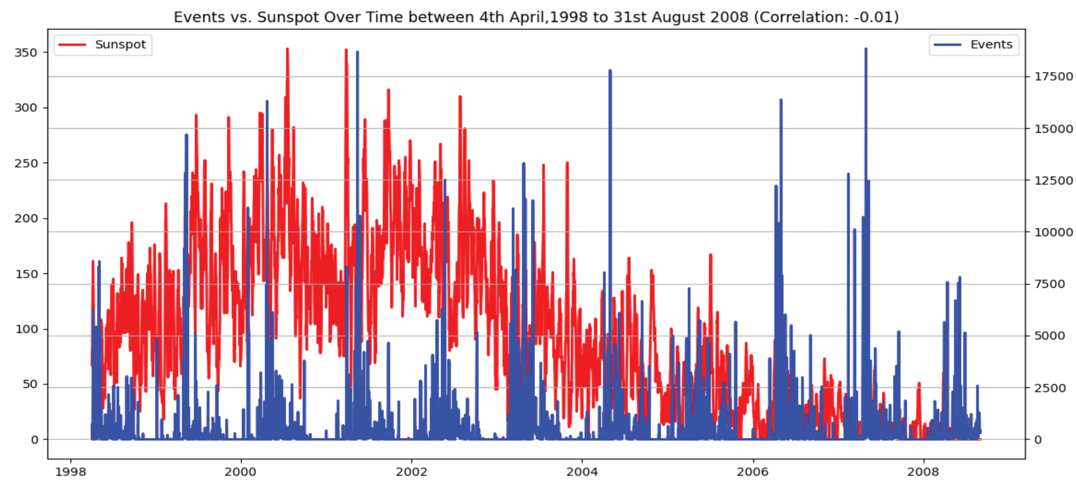

Fig. 2. A whole time series correlation between Sunspot and lightning

Interpretation of the result

The correlation coefficients are found to be different for different time sections which indicates the temporal relation but most of the correlations are found to be non significant even for the smoothed values as well. However, there are some instances of time period where the correlations are found to be strong. It could be the mere coincidence of finding such notable correlation or there could possibly exist the correlation which is hard to say. In the findings, the correlation between solar spot and lightning occurrence corresponds well with that of F10.7 index and lightning occurrences but not so well with solar speed.

While these findings contribute very less to our understanding of solar influences on lightning, it is essential to acknowledge the study's limitations. This is a very preliminary study hence a detailed and in-depth analysis is required for the further exploration to understand the influence of solar activity on lighting occurrences.

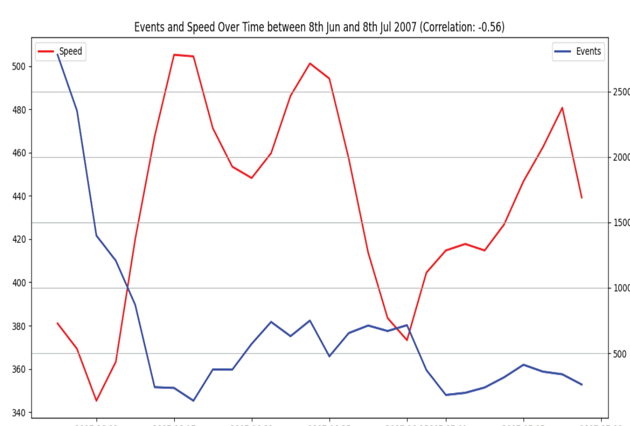

Fig .3. A graphical visualization of correlation between raw and smoothed value of solar speed and lightning occurrence in time period of 8th June to 8th

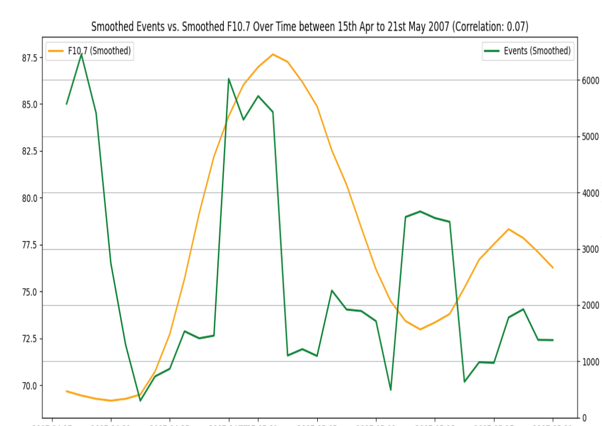

Fig. 4. A graphical visualization of correlation between raw and smoothed value of F10.7 Solar index and lightning occurrence in time period of 8th

Limitation and Conclusion

Limitation

A primary limitation of this study is the availability and quality of data. Data on lightning events, sunspot numbers, F10.7 values, and solar wind speed were obtained from various sources, and while efforts were made to ensure data accuracy, there may still be limitations and uncertainties associated with the data used. Missing or incomplete data points could impact the analysis. The relation between lightning and solar activity is quite complex and there may exists the time lag relation between them which isn't accounted in this study.

Conclusions

This study has explored the relationship between solar activity parameters (sunspot numbers, F10.7, solar wind speed) and lightning events in the context of Solar Cycle 23. While addressing the aforementioned limitations, several key findings have emerged:

Variable Correlations: The analysis revealed varying degrees of correlation between solar activity parameters and lightning events throughout the selected time periods. Some periods exhibited significant correlations, while others did not. Notably, the time period of April 9 to April 29, 2000, demonstrated a particularly strong correlation between solar wind speed and lightning occurrence.

Complex Relationships: The study underscores the intricate nature of the relationship between solar activity and lightning. High correlations with one solar parameter were sometimes accompanied by low correlations with others, highlighting the multifaceted influences.

While these findings contribute to our understanding of solar influences on lightning, it is essential to acknowledge the study's limitations. Future research can build upon these insights by exploring additional datasets, considering more extended timeframes, and delving deeper into the underlying mechanisms of this intriguing relationship. This study serves as a stepping stone for further investigations into the complex interplay between solar activity and terrestrial weather phenomena.

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