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RESEARCH ARTICLE

Impact of Thunderstorm Activities on Tropospheric NO_X Over Koshi Province of Nepal and Their Possible Role in Climate Change

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Highlights

- This work examines the association of lightning stroke density with the tropospheric Nitric/Nitrogen Oxides (NOX) over the Koshi province (eastern part) of Nepal, during monsoon pre-monsoonand post-monsoon seasons for three consecutive years.
- The principal aim of this analysis is to study the relationship between lightning stroke density and average NOX during the lightning season.
- A positive correlation, in range of 0.6 to 0.7, between lightning and the tropospheric NOX has been observed during the pre-monsoon seasons as well as post-monsoon seasons.
- In seasonal comparison, the correlation is slightly declined in post-monsoon than pre-monsoon.

Abstract

Lightning, a natural atmospheric phenomenon, plays a significant role in altering atmospheric chemistry and air quality by generating nitrogen oxides (NO_X). This research aims to explore the correlation between lightning stroke density and atmospheric NO_X over Koshi Province of Nepal by using observational data. Over the course of three year (2018,2019 and 2020), sessional (lightning pre-dominant; pre-monsoon and post-monsoon) measurements of lightning activity (lightning stroke density) were obtained from Global Lightning Dataset (GLD 360) and NO_X data acquired from NASA's Ozone Monitoring Instrument (OMI). The computation was conducted by using programming language PYTHON. Correlation analysis was performed to examine the relationship between lightning stroke density and NO_X concentrations by considering lightning stroke density as independent variable and average NO_X as dependent variable. Our analysis shows a notable positive correlation between lightning stroke density and average NO_X over Koshi Province of Nepal. The values of correlation coefficient (R) was found 0.625, 0.630 and 0.511 in pre-monsoon of years 2018, 2019 and 20120 respectively and 0.654, 0.605 and 0.370 respectively in post-monsoon.. Increased lightning activity corresponded to heightened NO_X concentrations, especially during pre-monsoon and post-monsoon. These results indicate that lightning significantly contributes to NO_X emissions in Koshi Province. Understanding the relationship between lightning and NO_X is essential for study atmospheric chemistry and assessing the impact of lightning on atmosphere.

Keywords: *Lightning, NO_X, GLD-360, Climate change, Nepal*

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Introduction

More than 150 years ago, in the time of Benjamin Franklin, it was believed that the spark generated in the lab is known as lightning. But, Lightning is a meteorological electromagnetic discharge of energized matter during thunderstorms, volcanic eruptions and so on [1]. Lightning is still one of the least understood natural phenomena despite being one of the most well-known and well-recognized. Paradoxically the most fundamental concerns of how lightning starts in the core of storm-cloud and spreads over many tens of kilometers have only just started to be answered. Due to unforeseeable and evanescent property of lightning stroke, the direct measurement inside lightning channels is very risky and challenging so the concept of remote sensing is developed. Aerial satellite photography, rocket lunched technology, cartography, forest site mapping and so on make it easy for the new invention about the nature and property of lightning. The recent identification of powerful flashed like X-rays & gamma-rays connected to thunderstorms and lightning also shows that intriguing new physics is continually being uncovered in our environment [2]. Mathur et al [3] defined as lightning is a elongated spark of electrical discharge. Huge numbers of lightning channels are generated in short period of time and travels randomly in any direction up to 5-10 KM at a time with continuity. About more than 90% lightning discharges are cloud to cloud discharge and around 10% are cloud to ground discharge. In percentage 10% is not huge but 30-100 discharges per second in ground is huge. Of the total lightning discharges, Cloud-to-ground discharges globally 25% that occurs in ground and the 75% do not involve in ground [4].

The threat of lightning is deadly and devastating for immediately as well as long term effect in the territory. Short time reverberations like causalities and fatality, while long terms effects like NO_X production and forest fire ignition. Lightning has risky to aviation system, air turbine – a renewable energy system, electrical power transmission line and soon. While it is challenging to provide an exact forecast of future lightning patterns, the convergence of factors such as expanding metropolitan regions, rising populations, and a warming climate strongly suggests an inevitable escalation in the risk of human exposure to lightning-related dangers [5].

Nitrogen oxides (NOx) are pivotal air pollutants, influencing atmospheric chemistry. Comparative analysis between Ozone Measuring Instrument (OMI) NO2 records and in situ surface measurements from the US Environmental Protection Agency and the Texas Commission on Environmental Quality networks in Texas reveals a correlation between 0.2 and 0.8, strengthening to over 0.5 for monthly averages. The study further uncovers significant NO2 reductions in highly populated areas alongside substantial increases in oil and gas producing regions, while observing a temporary but substantial decrease of up to 60% in NO2 levels during the COVID-19 pandemic, highlighting the potential of technological advancements in NOx emission control [6].

The lightning activities thoroughly in Nepal is primarily studied in first time. For this experiment, the satellite-based lightning imaging sensor is used to analyze the data over Nepal from 1998 to 2013. To compare the date from satellite based lightning imagining sensor, two ground based lightning detection networks World Wide Lightning Location Network (WWLLN) and the Global Lightning Network (GLN) is used to compare the 2011, 2012 and 2013's data. From this analysis, it is concluded that that peak time of lightning in Nepal is April and May instead of previously known June [7].The topographical variation in Nepal, ranging from Himalayan peaks to southern plains, significantly influences lightning occurrence and human casualties. Leveraging Vaisala's Global Lightning Dataset GLD360 and recent lightning casualty data from 2011 to 2020, this study reveals over one million lightning strokes annually, with least stroke density in high elevations, moderate in hilly regions, and frequent in the south. Despite its ranking as the second highest killer after earthquakes, lightning fatalities exhibit regional disparities, with the highest fatality rate of 3.8 deaths million−1 year−1 among South Asian countries, concentrated mainly in the central regions rather than high mountains [8]. Ministry of Home Affairs (MOHA) through its official portal Disaster Risk Reduction (DRI) clarify that lightning is the second highest natural disaster kill the human beings after earthquake each year. It kills approximately

108 people per year. Fatality rate in upper mountain region is low due to low inhabitants density and lower lightning stroke density over Nepal. Among all the natural calamity in Nepal, lightning is the second leading cause of death after earthquakes [9].

Methodology

In this study a Koshi province, eastern part of Nepal is divided into 10 × 10 km latitude and longitude matrix plot. Koshi province is located at east longitude from 86°1´ to 88°3´ and north latitude of 28°2´ to 26°3´. From matrix plot altogether 273 grid plots are plotted by using Python programming language.

Fig. 1. Location of Koshi Province in Nepal

The lightning data is extracted from the satellite based lightning detection network from VAISAL's Sweden called Global Lightning Dataset (GLD) 360. GLD 360 observe the daily lightning date all around the world every day from earths lightning detection network.

In this study NO_X data is wrench out from Ozone monitoring instrument (OMI) which measures the daily oxides, nitrates, nitrides, smokes, and so on.

From coding language Lightning and NO_X data is plotted by using statistical tool,

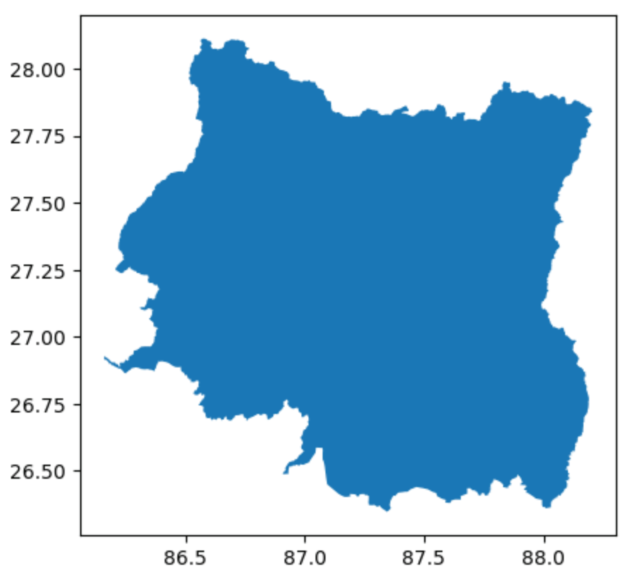

Fig. 2. Geologicalcal plot of Koshi Province

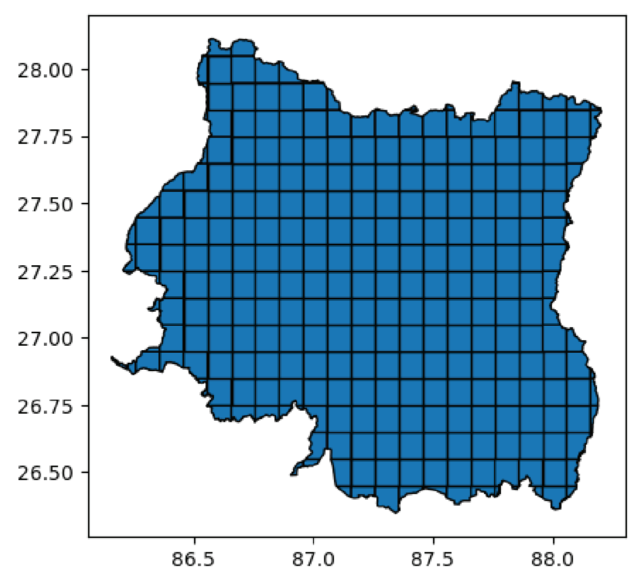

Fig. 3. Geological map of Koshi Province in 10 × 10 grid

Result and Discussion

The relationship among lightning stroke density and average OMI NO_X ($NO + NO_2$) was studied over the Koshi province of Nepal. The data of pre-monsoon (March, April and May) and post-monsoon (August, September and October) from 2018 to 2020 was plotted in the graph. The main purpose of this analysis is to identify the interrelationship between lightning stroke density and average NO_X over Koshi province of Nepal. The plot was made more precise and more accurate by eliminating the zero lightning stroke density and outlier/s values.

Plot of Lightning Stroke Density and Average NO_x, Pre-monsoon and Post Monsoon

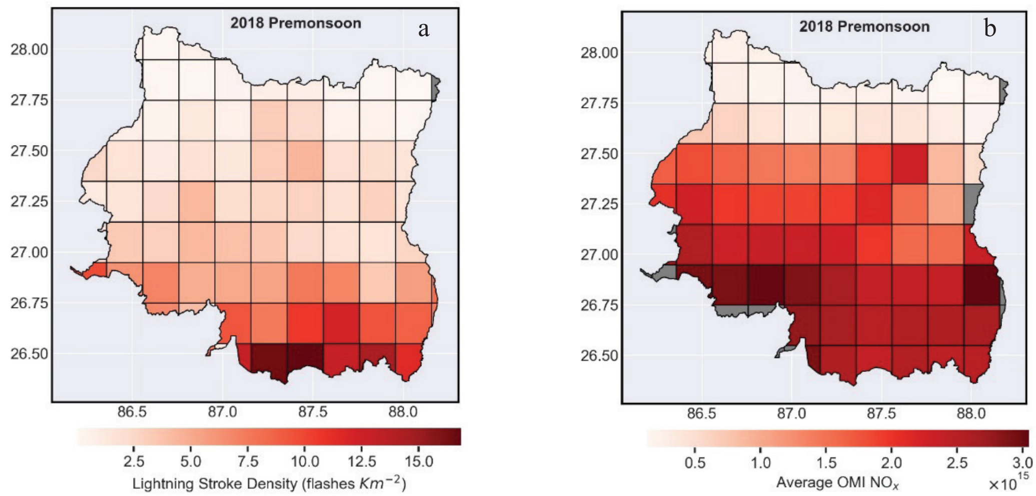

Fig. 4. (a) Lightning stroke density and (b) Average NO_X in pre-monsoon (2018)

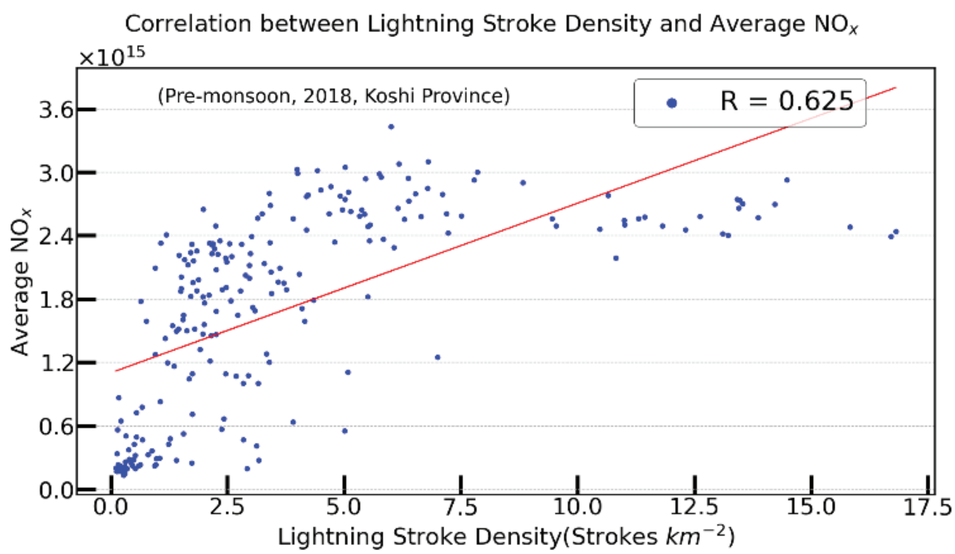

Fig. 5. A plot for correlation coefficient between the lightning stroke density and average NO_X in Pre-monsoon (2018)

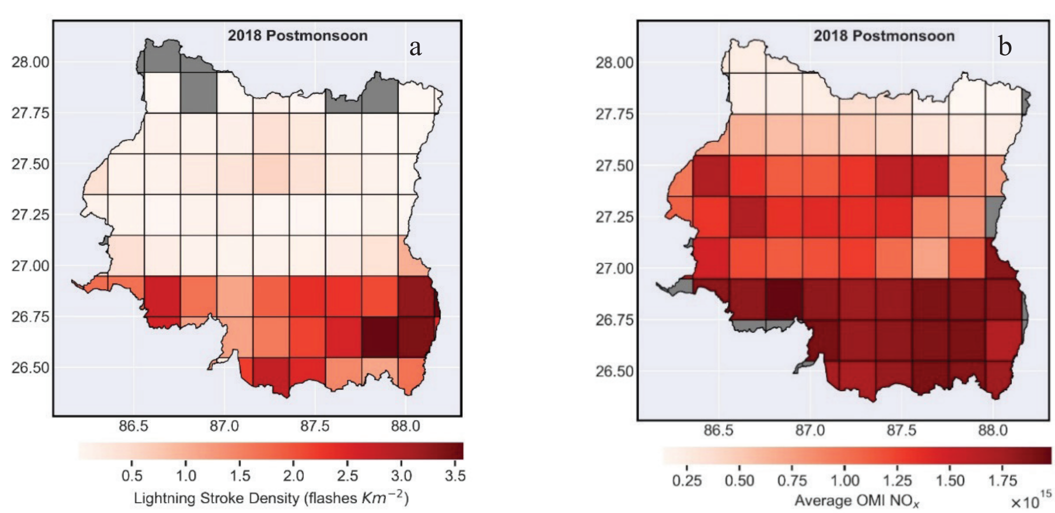

Fig. 6. (a) Lightning stroke density and (b) Average NO_X in post-monsoon (2018

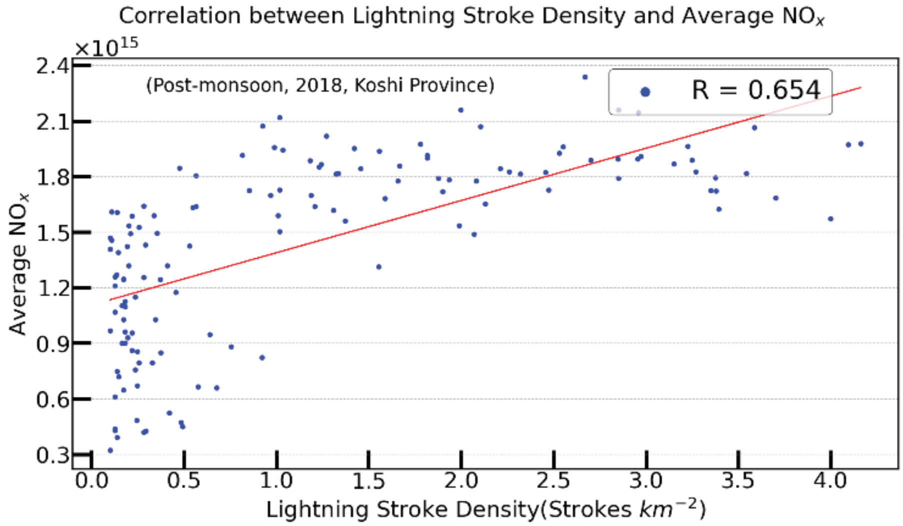

Fig.7. *A plot for correlation coefficient between the lightning stroke density and average NO_X for Post-monsoon (2018)*

As noticed from the graphs, the strong positive correlation is observed in pre-monsoon of 2018 with value 0.625 while in post-monsoon correlation is slightly greater than the correlation in pre-monsoon with a value of 0.654.

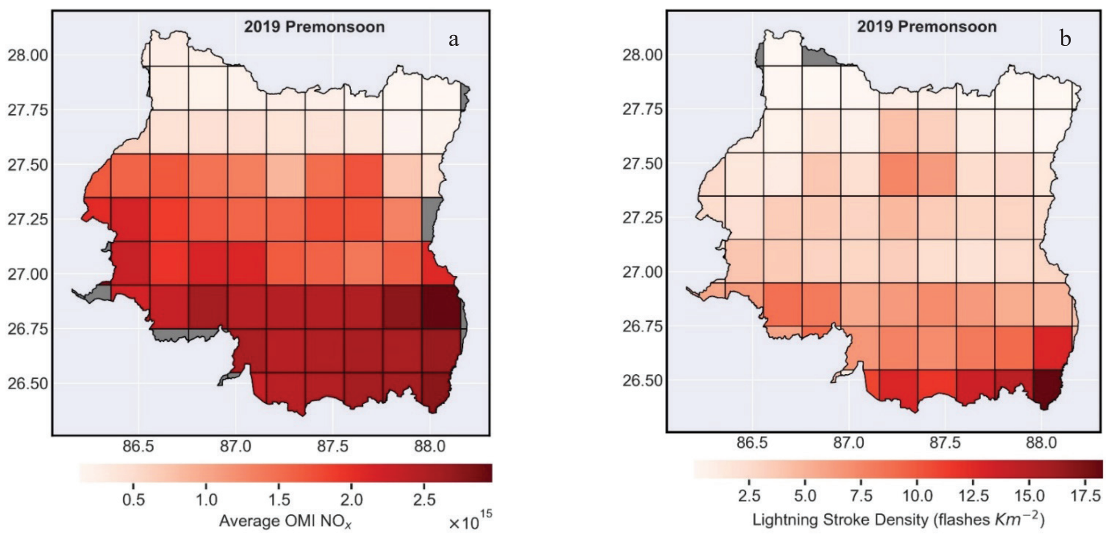

Fig. 8. (a) Lightning stroke density and (b) Average NO_X in pre-monsoon (2019)

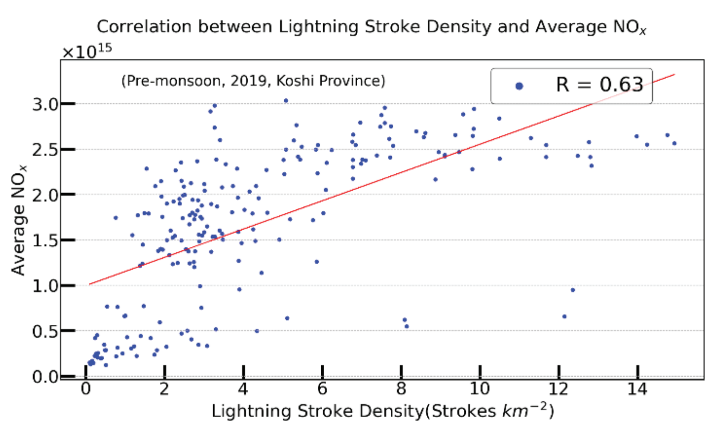

Fig. 9. A plot for correlation coefficient between the lightning stroke density and average NO_X for Pre-monsoon (2019)

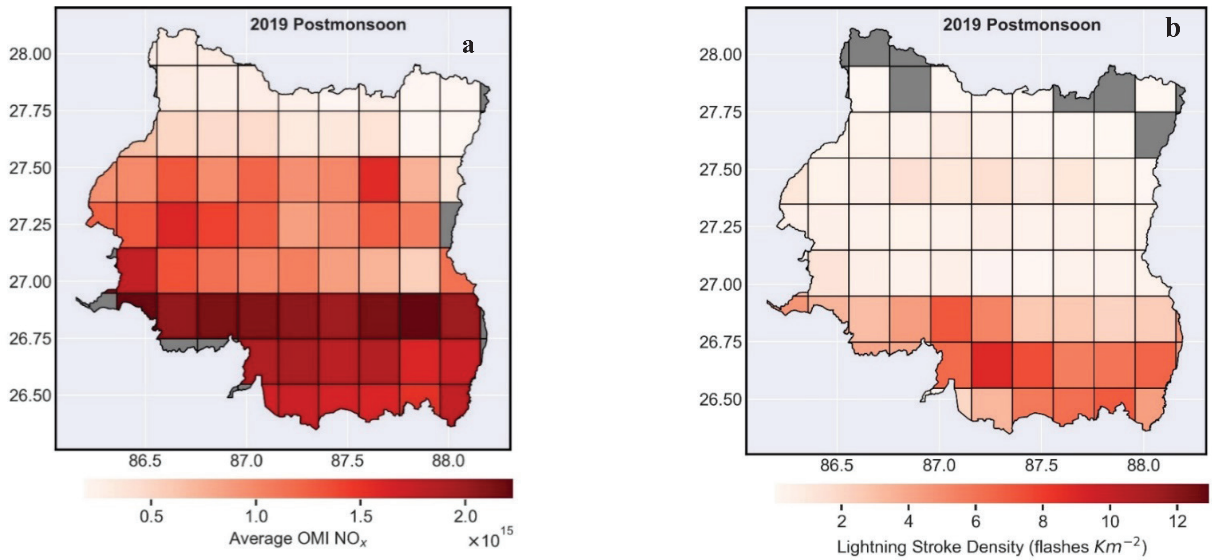

Fig. 10. (a) Lightning stroke density and (b) Average NO_X in post-monsoon (2019)

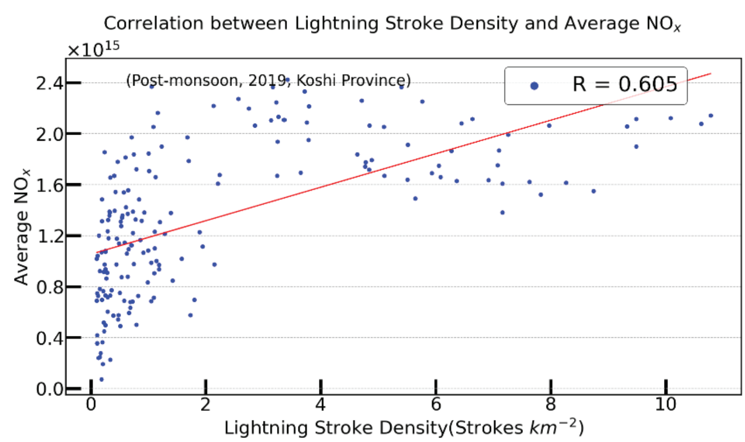

Fig. 11. A scatterplot for correlation coefficient between the lightning stroke density and average NO_X for Post-monsoon of year 2019.

As observed from the graph, the association between lightning stroke density and average NO_X in pre-monsoon of 2019 over Koshi Province of Nepal is quiet higher than that in post-monsoon. But both correlations are positive.

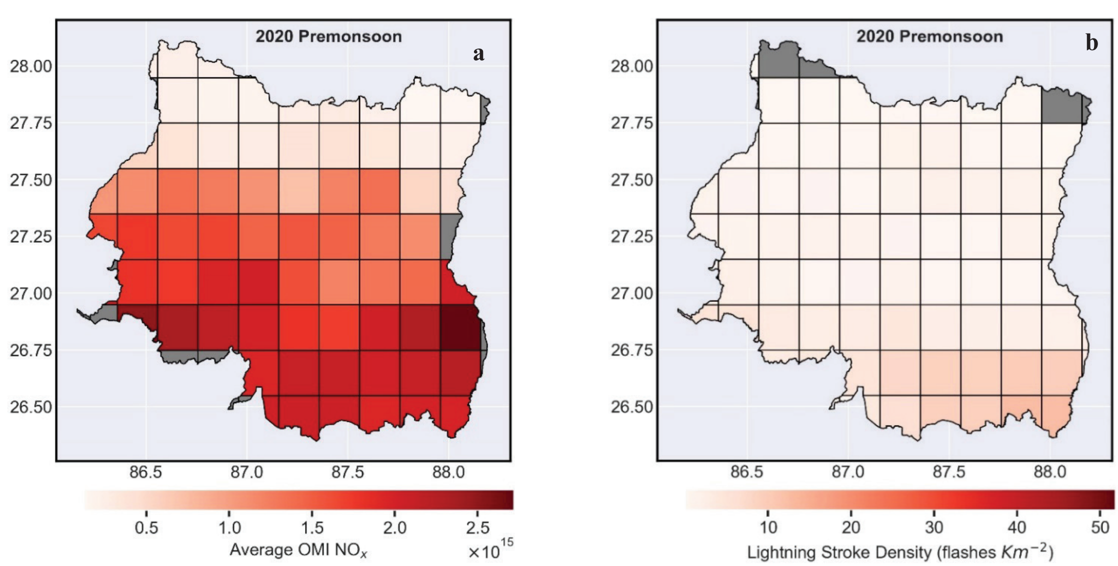

Fig. 12. (a) Lightning stroke density and (b) Average NO_X in pre-monsoon (2020)

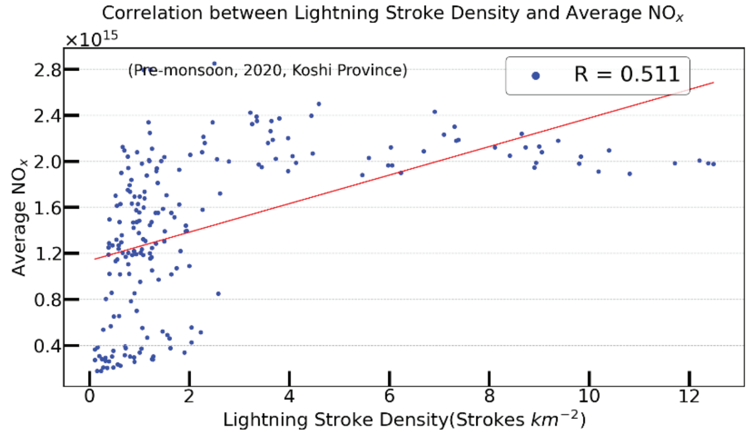

Fig. 13. A scatterplot for correlation between the lightning stroke density and average NO_x for Pre-monsoon of year 2020.

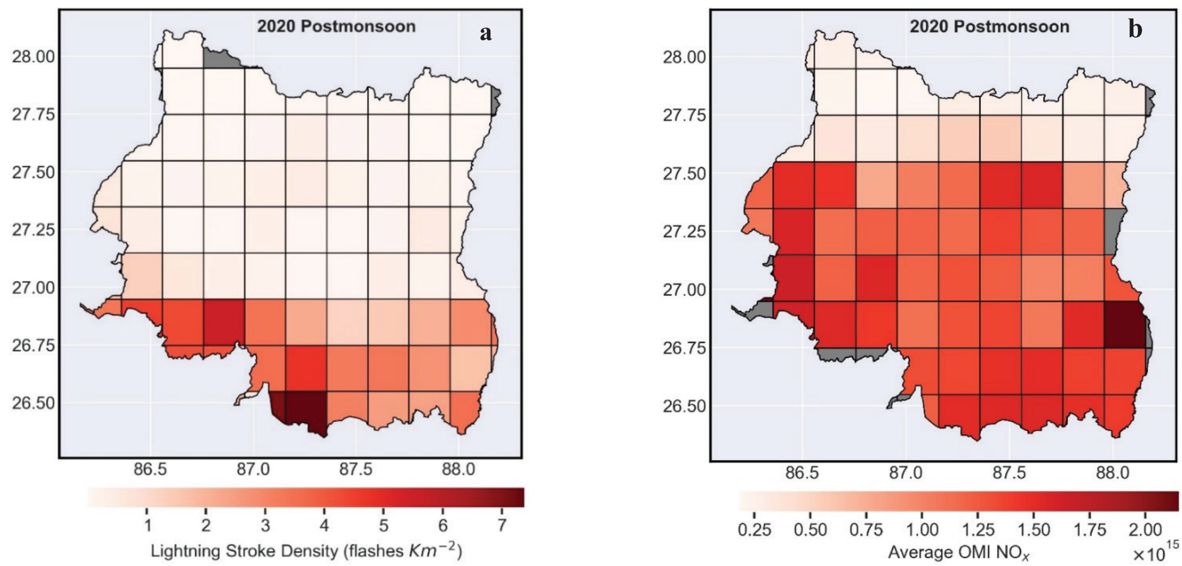

Fig. 14. (a) Lightning stroke density and (b) Average NO_x in post-monsoon (2020)

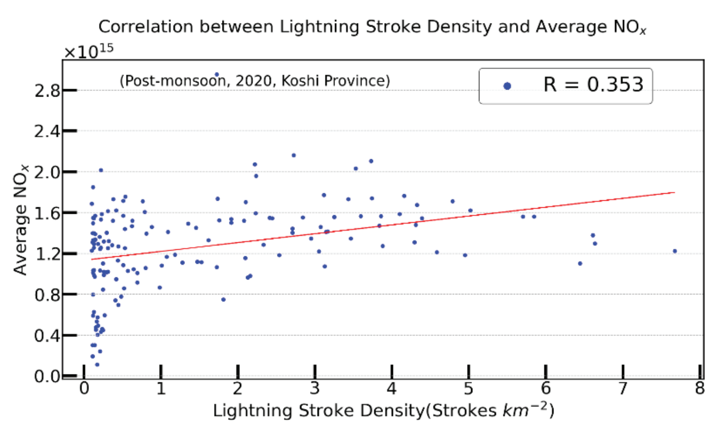

Fig. 15. A scatterplot for correlation between the lightning stroke density and average NO_x for Post-monsoon of year 2020.

Figure 12 clearly told that, in pre-monsoon of 2020 the correlation is positive but very less value than the result of pre-monsoon 2018/2019 with Karl Pearson's correlation coefficient value 0.511. Besides of other plots, in post-monsoon of 2020 the correlation in weak with value 0.353. This shows that in post-monsoon the atmospheric NO_x is not strongly associated with the lightning activities.

Conclusions

In conclusion, our research has shed light on the significant correlation between lightning stroke density and average NOx concentrations over the Koshi province of Nepal. The positive correlation coefficient ($0.35 < R < 0.65$) indicates a clear relationship between these two variables, highlighting the influence of lightning activity on atmospheric chemistry and air quality in the region. This correlation has important implications for understanding the sources and dynamics of NOx pollution in Nepal's Koshi province, particularly in relation to natural phenomena such as lightning strikes. Our findings underscore the need for continued monitoring and analysis of both lightning activity and NOx concentrations to better understand the complex interactions between atmospheric processes and pollutant emissions in the region. By gaining insights into the spatial and temporal patterns of lightning stroke density and average NOx levels, policymakers and environmental agencies can develop targeted strategies for mitigating air pollution and improving public health outcomes in Nepal.

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