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Some Important Observations regarding the Atmospheric Pollutants and Meteorological Parameters on Pre-monsoon CG Lightning and Pre-CG Lightning Days during Pre-lockdown, Lockdown and Post-lockdown Period in Kolkata, India†

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Abstract: The current study examines the changes of air pollutants and the values of some meteorological parameters on pre-monsoon (March-May) thunderstorm cloud to ground (CG) lightning days in 0.30×0.30 grid surrounding Kolkata (Dumdum) (22° 34' N, 88° 24' E), India, from 2019 to 2022.The Rabindra Bharati and Victoria regions in and around Kolkata are chosen for this study based on data availability. The research shows that most of the air pollutants, quantifiable meteoro-logical parameters, and pre-monsoon thunderstorm cloud to ground (CG) lightning flashes are at their lowest in 2020 and 2021.Furthermore, there is no structural differencebetween thun-derstorm cloud to ground (CG) lightning and pre-CG lightning days.

Keywords: Cloud to ground (CG) lightning flash; Pre-monsoon; atmospheric pollutants; quantified meteorological parameters; thunderstorm; COVID-19 lockdown; Pre-CG lightning (Pre-L); Lightning (L),Rabindra bharati (RB); Victoria (V)

1. Introduction

Convective activity is one of the most essential meteorological phenomena and plays an important role in atmospheric energetics and the hydrological cycle. Cloud to ground CG lightning activity associated with the convective systems is a useful index of the associated precipitation [1]. This contributes substantially to the annual total rainfall over the Indian region [2]. Atmospheric pollutants affect the development and formation of local weather systems. Hobbs et al., [3] have worked on weather and climate modification by atmospheric pollutants. Thunderstorm CG lightning has been one of the major concerns of meteorological scientists. Westcott in 1995 first documented the enhanced CG lightning activity due to urban effects over the cities [4]. Later on, Petersen and Rutledge (1998) [5] showed positive correlations between CG lightning flash density and rainfall amount. Afterward, many studies have been carried out to discover the effect of an urban area on the initiation and enhancement of CG lightning [6–8]. The main objective of this study is to analyze the change in the emission of ambient atmospheric pollutants and meteorological parameters with pre-monsoon thunderstorm CG lightning during the pre-lockdown, lockdown and post-lockdown periods.

2. Materials and Methods

2.1. Materials

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The atmospheric pollutant data [$PM_{2.5}$ ($\mu g/m^3$), PM_{10} ($\mu g/m^3$), NO_2 ($\mu g/m^3$), SO_2($\mu g/m^3$), CO($\mu g/m^3$) and Ozone ($\mu g/m^3$)] have been collected from the National Air Quality Index, CPCB, India (https://app.cpcbccr.com/AQI_India/) for both pre-monsoon thunderstorm CG lightning and pre-CG lightning days. Meteorological data of Dumdum, Kolkataare taken from the Department of Atmospheric Sciences at the University of Wyoming. Thunderstorm data for the pre-monsoon period over Kolkata during the years 2019 to 2022 are collected from the Regional Meteorological Centre, Indian Meteorological Department, Alipore. CG lightning data [(0.3^0× 0.3^0) keeping Rabindra Bharati as center] are collected from IITM, Pune.

2.2. Methods

In the literature, all the symbols used in the statistical analysis have their usual meanings. To analyze the changes in atmospheric pollutants and quantified meteorological parameters with thunderstorm CG lightning days during the pre-lockdown, lockdown, and post-lockdown periods, relevant quantitative simple statistics are used.

- i) Regression lines are drawn to find out the relationship between the total emission of atmospheric pollutants and thunderstorm CG lightning flash counts at Rabindra Bharati(RB) and Victoria (V) during the period of study (2019-2022) (Fig.1a).
- ii) Next, regression lines are also drawn to find out the relationship between the quantified meteorological parameters and thunderstorm CG lightning flash counts at Kolkata (Dumdum) during the period of study (2019-2022) (Fig. 1b).
- iii) Pearson correlation coefficients (R) are computed for the years 2019,2020,2021 and the significance tests are done using the t statistic,where, $t=R/S_R$, $S_R=\sqrt{[(1-R^2)/(n-2)]}$, n being the total number of observations and S_R is the Standard Deviation. Significance test is done with $R^2 \geq 0.2$. The t test can be used to test the null hypothesis, H_0: $X_i = Y_i$ at 5% significance level, where Xi and Yi refer two different variables that are being compared.

$t_{critical\ (0.05)}$ = critical value of t at 5% significance level. If $t_{observed} \leq t_{critical\ (0.05)}$, then the null hypothesis is rejected, otherwise it is accepted.

- iv) Line graphs are drawn with atmospheric pollutants and meteorological parameters (on the Y axis) in pre-CG lightning and CG lightning days per year (on the X axis) (Fig. 2a and 2b).
- v) Bar diagrams are drawn with atmospheric pollutants(on the Y axis) on thunderstorm CG lightning days per year (on the X axis)(Fig. 3a).
- vi) A bar diagram is drawn with total thunderstorm CG lightning flash counts (on the Y axis) per year (on the X axis) over the study area (Fig. 3b).
- vii) Bar diagrams are also drawn with quantified meteorological parameters (on the Y axis) on thunderstorm CG lightning days per year (on the X axis)(Figs. 4a and 4b).

3. Results and Discussion

1. Though the regression lines between the air pollutants and the thunderstorm CG lightning flash counts apparently indicate that they have a linear relationship,but the linear correlation coefficients are not 5% significant in most of the cases except in a few.The linear correlation coefficients are significant at 5% level only for $PM_{2.5}$ and PM_{10} in 2019 and 2020 at both Rabindra Bharati and Victoria. One of the figures among many is furnished below as an example [Fig 1a].

Also from the regression lines of the quantified meteorological parameters and the thunderstorm CG lightning flash counts,it has been found that there is no significant linear relationship between them, as far as the present dataset is concerned. One of the figures among many is given below as an example [Fig 1b].

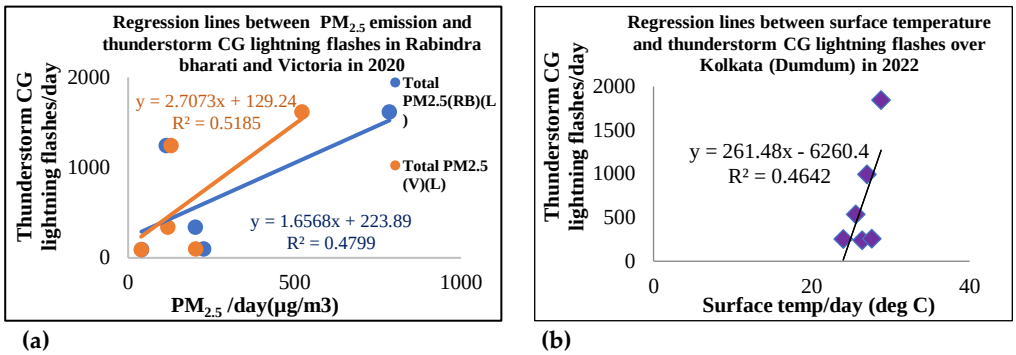


Figure 1. (a) Regression lines of $PM_{2.5}$and thunderstorm CG lightning flashes in 2020 over Rabindra Bharati(RB) and Victoria(V); **(b)**Regression lines of Surface temperature and thunderstorm CG lightning flashes in 2022 over Kolkata(Dumdum).

2. The line graphs depict that there are no specific changes in atmospheric pollutants emission present in thunderstorm CG lightning and pre-CG lightning days at both Rabindra Bharatati and Victoria during the study period. Here also one figure among many is presented below as an example [Fig 2a].

Also the line graphs of the quantified meteorological parameters on thunderstorm CG lightning and pre-CG lightning days depict that, in most of the cases, there is no structural difference between them. Here also one of the figure among many is given below as an example [Fig 2b].

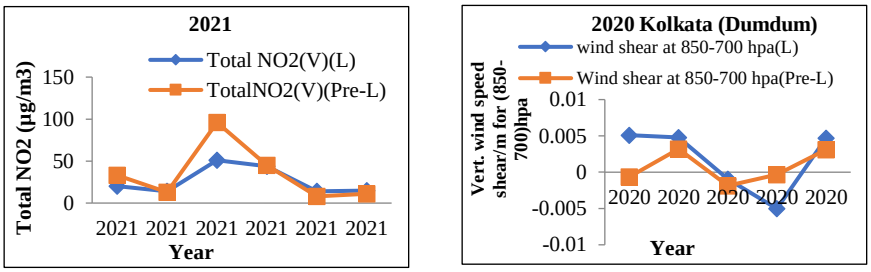


Figure 2. (a) Line graph of total NO_2 in CG lightning(L) and pre-cg lightning(Pre-L) days on Victoria(V) in 2021; **(b)**Line graph of vertical wind speed shear for (850-700) hPa layer in CG lightning and pre-lightning days in 2020 over (Dumdum)Kolkata.

3. The bar diagrams of emission of atmospheric pollutants during the period of study depict that the air pollutants $PM_{2.5}$, PM_{10}, NO_2, CO at Rabindra Bharati and Victoria are at their minimum in either 2020 or 2021 or in both. It is to be noted that 2020 and 2021 are considered as complete and partial lockdown due to the Covid-19 surge.Here also only one of the figure among many is given below as an example [Fig 3a,Table 1].

During this time period, thunderstorm CG lightning flashes are also lower than those of the pre and post-lockdown time spans (Fig 3b).

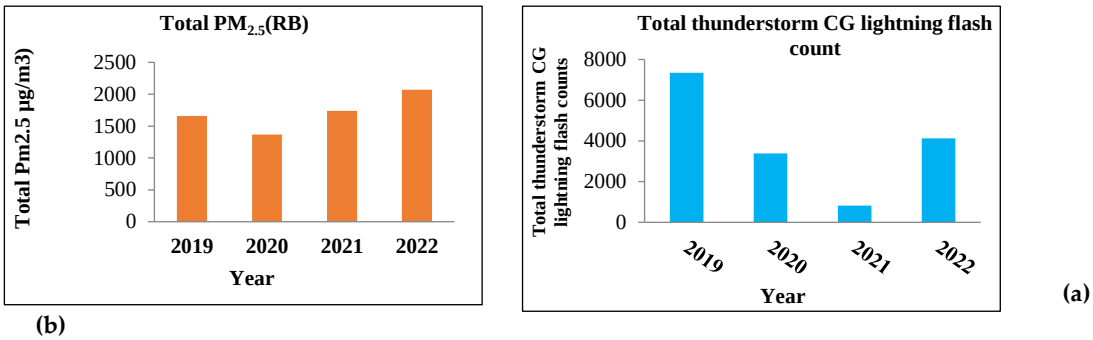


Figure 3. (a) Bar diagram of total $PM_{2.5}$ in CG lightning days on Rabindra Bharati (RB) during 2019-2022;**(b)**Bar diagram of total lightning flash counts over Kolkata area during 2019-2022.

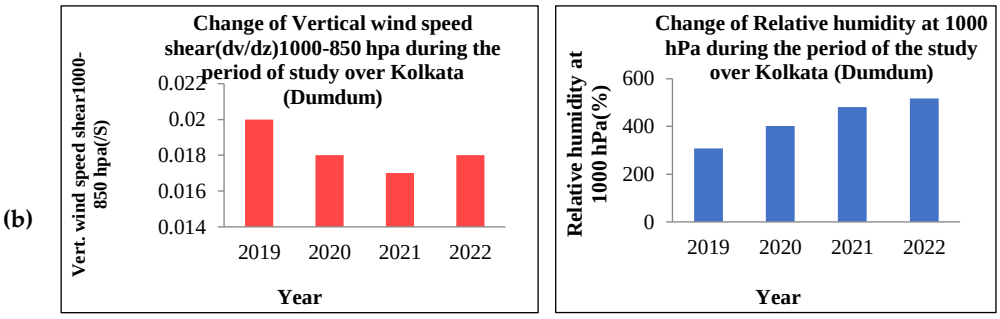
Table 1. Minimum emission of atmospheric pollutants in Rabindra Bharati and Victoria during the study period.

Sl no	Name of the atmospheric pollutants	Minimum Emission in year/s	
		Rabindra Bharati	Victoria
1	$PM_{2.5}(\mu g/m^3)$	**2020**	**2021**
2	$PM_{10}(\mu g/m^3)$	**2020,2021**	**2021**
3	$NO_2(\mu g/m^3)$	2022	**2021**
4	$SO_2(\mu g/m^3)$	2019	2022
5	$CO(\mu g/m^3)$	**2020**	**2021**
6	Ozone $(O_3)(\mu g/m^3)$	2019	2019

(bold values in the table represent the minimum emission of the atmospheric pollutants over the study region during the study period).

4. In the bar diagrams of the quantified meteorological parameters during the study period, it is observed that wind speed at 1000 hPa ,850 hPa and 700 hPa, vertical wind speed shear for (1000- 850) hPa and (850-700) hPa layer, precipitable water content over the entire sounding, and dew point temperature at 700 hPa show minimum values during the years 2020–2021.In this case also one of the figures among many is given below as an example [Fig 4a, Table 2].

- **Anomalies**:The quantified meteorological parameters (surface temperature, dew point temperature at 1000 hPa, CAPE and relative humidity at 1000 hPa,700 hPa and 500 hPa level) and some air pollutants (SO_2 and Ozone) have been found to increase when the lightning flash counts decrease during the years 2020 and 2021.The following adjacent figure among many represents such anomalies as example (Fig. 4b).The reasons behind such anomalies are yet to be explored.



a) b)

Figure 4. (a) Bar diagram of change in vertical wind speed shear for (1000-850) hPa layer during 2019-2022 over Kolkata(Dumdum); **(b)**Bar diagram of change in Relative humidity at 1000 hPa during 2019-2022 over Kolkata(Dumdum).

Table 2. Meteorological parameters were found Minimum during the study period (2019-2022).

Sl no	Name of the Meteorological parameters	Minimum in year/s
1	Surface temp(deg C)	2019
2	Dewpoint temp at 1000 (deg C)	2019
3	Dewpoint temp at 700 (deg C)	**2021**
4	CAPE(J/Kg)	2019
5	wind speed(m/s)at1000hPa	2019
6	wind speed(m/s)at850hPa	**2021**
7	wind speed(m/s) at700hPa	**2021**
8	Vertical Wind speed shear (dv/dz)(s-1) 1000-850 hPa	**2021**
9	Vertical Wind speed shear (dv/dz) (s-1) 850-700 hPa	**2021**
10	Precipitable water content (mm)	**2020**
11	Relative humidity(%) at 1000 hPa	2019
12	Relative humidity(%) at 700 hPa	2019
13	Relative humidity(%) at 500 hPa	2019

(bold values in the table represent the minimum values of meteorological parameters during the study period over the study region).

4. Conclusion

Only thunderstorm CG lightning days with pre-monsoon thunderstorms are considered in a $0.3^0 \times 0.3^0$ grid which includes many stations around Kolkata. But sufficient data is available only at Rabindra Bharati and Victoria.So, it is very hard to come to a specific conclusion with this insufficient data set. Yet it is interesting to note that some following features are observed clearly even with the limited data set.

- a)From the bar diagrams of the atmospheric pollutants, the observations reveal that the emission of $PM_{2.5}$, PM_{10}, CO, NO_2 and total pre-monsoon thunderstorm CG lightning flashes are at minimum in the complete lockdown period.
- b) The bar diagrams of the quantified meteorological parameters show that the wind speed at 850 hPa and 700 hPa level, vertical wind speed shear for (1000-850) hPa and (850-700) hPa layer, and total pre-monsoon thunderstorm CG lightning flashes are minimum either in 2020 or in 2021.
- c) The meteorological conditions are almost the same on pre-lightning and thunderstorm CG lightning days, which suggests that some other parameters are responsible for the phenomenon, which may be explored in future.
- d) Regarding the emission of the atmospheric pollutants, the emission are found to be minimum either in 2020 or in 2021, when the total thunderstorm CG lightning flash counts are also found minimum.
- e) It is observed from the bar diagrams the emission of atmospheric pollutants and quantified meteorological parameters on thunderstorm CG lightning days are minimum inthe years 2020 and 2021.But these are found to be maximum or close to maximum in the year 2022, which is a post-lockdown period. The years 2020 and 2021 are very important because of the Covid-19 pandemic surge. During that lockdown period, transports were completely stopped, maximum factories were closed (except for Covid-19 emergency purposes) in Kolkata (India), which are considered as the main sources of atmospheric pollutants. That is why some changes are noted in the emission of atmospheric pollutants and quantified meteorological parameters during

2020 and 2021, which directly or indirectly affect the thunderstorm CG lightning flash counts over the region of study.

- f) It is well known that thunderstorm CG lightning is a complex phenomenon. To analyse the situation, more information is needed. So the study needs to be continued in the future with an adequate number of data points.

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