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Effect of meteorological parameters and environmental pollution on thunderstorm and lightning activity over an urban metropolis of India

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ABSTRACT

The purpose of this study is to understand the effect of meteorological parameters and environmental pollution on thunderstorm and lightning activity over Kolkata (22.65° N, 88.45° E), India during the pre monsoon season (April–May). The aerosol optical depth, cloud top temperature and lightning flash rate are analyzed with 2004–2010 observations. The convective available potential energy (CAPE) and convective condensation level (CCL) are utilized to view the role of convective energy and level of cloud base in thunderstorm and lightning activities. The suspended particulate matter (SPM), sulfur oxides (SO_x) and nitrogen oxides (NO_x) are also considered for a precise understanding of the effects of all these parameters on thunderstorms and lightning activity. High variability in convective energy persists over Kolkata during the pre monsoon season. It is observed that high CAPE and lower CCL leads to maximum wind speed with thunderstorms. Irrespective of CCL heights the average concentration of SPM is observed to be high for increased lightning flash rate. It is revealed that increased surface pollution in a near storm environment can increase the lightning flash rate during thunderstorms. The result also shows that the enhanced lightning activity intensifies the production of tropospheric NO_2.

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Introduction

The effect of pollution on weather and climate has been a much discussed issue since a few decades. Different weather formation and the consequent development stages are affected by pollutant particles. The obvious question is that, how this variation affects the weather condition or how the degree of concentration varies with different stages of prevailing weather condition. Study of pollution meteorology over a particular station for a given time span requires knowledge about the interconnectivity between various meteorological parameters and pollutant particles. In recent years, interrelation between lightning and pollution has become a matter of concern. The influence of aerosols on cloud microphysics, rainfall and cloud electrification has been comprehensively studied and the effect of aerosol concentration on cloud electrification has been discussed by a number of authors. Hobbs et al. (1974) found that pollutants which affect clouds are most likely to produce modifications in weather and climate. The effect of aerosols on cloud microphysics is significant and occurs on a global scale (Bréon et al., 2002). The studies relating to the effect of an urban area on the local weather activities have been carried out by scientists over the globe (Changnon et al., 1981; Orville et al., 2001; Steiger et al., 1989; Soriano et al., 2001). Majority of these studies have attributed the effect to the urban heat island circulation with a possible role of air pollution. Pollution over the metropolis can elevate the cloud condensation nuclei (CCN) concentration, which in turn might produce changes in the microphysical processes taking place inside the clouds (Kar and Ha, 2003). The relationship between precipitation and lightning is found to be more consistent during pre-monsoon season compared to that of monsoon season over central Indian region (Lal and Pawar, 2009). Qie et al. (2004) stated that there is a high ratio of lightning flash density to rain rate over the Tibet Plateau during pre-monsoon season than that during monsoon season, and Yuan and Qie (2008) determined that mean cell-level flash rate during the pre-monsoon season is higher than that during monsoon season. Of late Liou and Kar (2010) studied the relationship between precipitation and cloud-to-ground lightning over Taiwan and found that the values of rain yield per lightning flash are different for inland and coastal stations. Engel-Cox and Holloman (2004) proposed good correlation between MODIS AOD and $PM_{2.5}$ (Particulate Matter of size 2.5 μm) in the eastern US but apparently more elusive in the western US due to a combination of the differences between ground-based and column average datasets, regression artifacts, variability of terrain etc. Many studies in the recent years have shown that lightning activity in a region can be affected by changes in thermo-dynamical properties as well as increase in aerosol concentration (Khain et al., 2008; Bell et al., 2008, 2009). The present study aims at identifying the effect of meteorological parameters along with atmospheric pollutants on lightning activity over Kolkata during pre-monsoon (April–May) thunderstorms (Chaudhuri, 2008a,b).

Materials and methods

The location of the study is Kolkata (22° 32′N, 88° 20′E), India. The thunderstorm records are collected from India Meteorological Department (IMD) during the pre-monsoon season (April–May) for the years 2004–2009. The total of 42 thunderstorms is taken for the analysis during the mentioned period. Heights of CCL (Convective Condensation Level), along with CAPE (Convective Available Potential Energy) are computed with Radiosonde/Rawinsonde data collected from http://www.weather.uwyo.edu website. The lightning data is collected from the LIS (Lightning Imaging Sensor) database. The LIS is a TRMM satellite-based instrument and detects cloud and ground lightning activities in the troposphere (Cecil et al., 2005). Both intra cloud and cloud to ground lightning flash rate are taken for the present study. The TRMM satellite has circled the Earth at an altitude of 350 km (The TRMM satellite was boosted from an altitude of 350–402 km in August 2001 to extend its mission life) with an inclination of 35°. The LIS sensor requires approximately 49 days returning to its original position relative to the Sun and the Earth, though the manual recommends using a 100-day window (Boccippio et al., 1998). LIS has a much smaller field of view but has higher detection efficiency than OTD (Optical Transient Detector) (Boccippio et al., 2002). Different other parameters like aerosol optical depth (AOD) and cloud top temperature (CTT) are collected from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite products. Tropospheric column amount of NO_2 data is collected from NASA's Ozone Monitoring Instrument (OMI) satellite products.