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Firework Induced Large Increase in Trace Gases and Black Carbon at Dibrugarh, India

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Abstract: Religious, occasional and annual fire work festivals worldwide are found to introduce high concentrations of pollutant gases and particulate matter into the atmosphere. These in turn alters the air quality of a region in the short and long time scales and affect human health adversely. The effect of fireworks on short-term variation in air quality of an urban location Dibrugarh, set amidst the rural environment of north-east India, was assessed from the ambient concentrations of O_3, SO_2, NO_x, CO and BC (black carbon) during the Diwali festival during Nov. 13-14, 2012. The firework activity in general peaks during evening to midnight hours. Substantial increase in concentrations of O_3, SO_2, NO_x, CO and BC was observed during the peak hours of firework activity (16:00 h to 22:00 h) in the Day 1 and Day 2 of the Diwali festival. However, the increase in concentrations from the background level was found to be highest on the post-Diwali day due to their accumulation in the atmosphere. The firework activity has not affected the regular diurnal pattern of the measured species during this episode.

Key words: O_3, NO_x, firework, black carbon, air quality

1. Introduction

The suspended PM (particulate matter) and trace gases (O_3, NO_x, CO, SO_2, CH_4, etc.) are the major atmospheric constituents influencing the atmospheric chemistry and climate mainly through impacting solar and thermal radiative transfer. The perturbations occur directly via scattering or absorbing solar radiation and indirectly through their effects on clouds by acting as cloud condensation nuclei or ice nuclei. As a result, the air quality as well as the thermal structure of the atmosphere can be affected by the presence of relatively small amounts of PM (or/and) radiatively active gaseous compounds O_3, CH_4, N_2O, etc.. Concentrations of trace gases/greenhouse gases and PM have risen in Earth's atmosphere due to human consumption of fossil fuels.

Religious and annual fire work festivals worldwide are common anthropogenic activity that alters the air quality of a region in the short and long time scales. Qualitative and quantitative estimation of the degradation of air quality due to such events has been the focus in recent times [1]. Significant increase in BC (black carbon) and greenhouse gas concentration has been reported during the Diwali or similar festivals in India and China [2-6]. Report by Wang [3] showed 3-7 times increase in these concentrations from normal days during the Lantern Festival. A study about the short term variation in air quality in Hisar, India during Diwali reported 2-10 times increase in concentrations of NO_2 and SO_2 over a typical winter day [5]. Similarly, Salkia, near Kolkata recorded 1.73 times increase for SO_2 and 1.27 times for NO_2 on Diwali compared to a typical winter day value [6]. An average increase in SO_2 and NO_x concentrations was observed over pre-Diwali period and a normal day by 1.95 and 6.59 times and 1.79 and 2.69 times respectively in Lucknow [7]. Report by Babu and Moorthy [4] showed three times increase in the

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concentration of BC over normal day level at Trivandrum during Diwali. Metal pollution in air due to fireworks during Diwali over a location in north east part of Hyderabad has also been observed [8]. The impact of fireworks on visibility and human health is particularly evident when the pyrotechnic exhibition is performed during stable meteorological conditions [9]. The use of colored sparklers by people, mostly children at ground level, put them at a high risk of inhaling the emitted pollutants. Burning of firecrackers and sparkles increased loading effects in human health severely especially in the infants, women and elderly people [10]. Together with particulate matter, literature also suggests that there is a strong relationship between higher concentration of SO_2 and NO_x and several health effects like cardiovascular diseases, respiratory health effects such as asthma and bronchitis, and reproductive and developmental effects such as increased risk of premature birth [11]. High levels of SO_2 get adsorbed on fine atmospheric particle matter which can be transported very deep into lungs causing serious damage to the lung tissues. Among the particles of diverse composition, sulfates have the worst health impact, which also stay in air for long time [12]. The health impact of air pollution depends on the pollutant type, its concentration in the air, length of exposure, other pollutants in the air and individual susceptibility. Report by Attri [2] showed that fireworks can produce O_3, a strong and harmful oxidizing agent at the ground level without the participation of NO_x.

In spite of the known harmful effects of fireworks on air quality and consequently on human health not many reports are available regarding the impact of fireworks from an urban location in a relatively clean environment with low population density and without heavy industrialization. The relative effect of the precursor gases on observed increase in the level of ozone have not been studied either. In this study, an attempt has been made to delineate the effect of fireworks during the Diwali festival on change in concentrations of trace gases viz. O_3, NO_x, CO, and SO_2 and BC over Dibrugarh (27.3º N, 94.6º E, 111 m amsl), North-East India. In the year 2012 the Diwali festival was celebrated in India during Nov. 13-14. To study the effect of fireworks on the ambient atmosphere over Dibrugarh round the clock measurement of the above mentioned species were carried out before, during and after the festival period. Maximum firework activity took place on the two Diwali days Nov. 13-14.

2. Study Location, Meteorology and Data

The study location Dibrugarh is a major town situated on the southern bank of river Brahmaputra in upper part of Assam, in North-East India (Fig. 1). It is surrounded by large number of tea plantations, rivers and rivulets. The NE India located at the sub-Himalayan range possesses unique topography with scattered hilly regions all around except a corridor in the west. Geographically, the location is surrounded by Himalayan range to the north, Bay of Bengal to south, west Asian and major part of Indian subcontinent to the west and highly polluted East Asian countries to the East, which results in a complex atmospheric environment. More detail on the

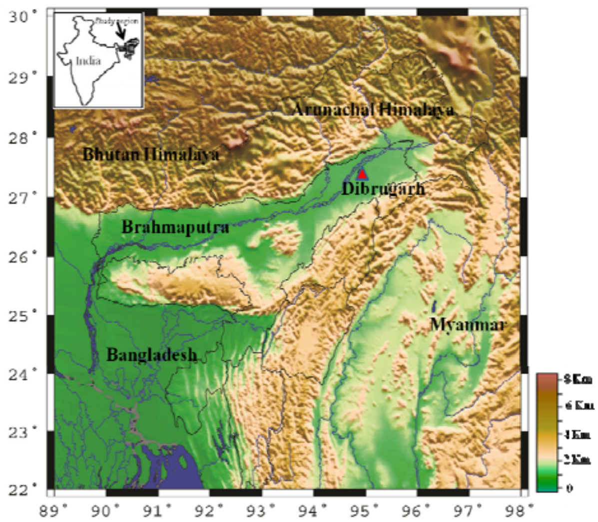

Fig. 1 Map showing north-east India and the adjoining regions. The study location Dibrugarh (27.3º N, 94.6º E, 111 m amsl) is identified (inset shows the map of India).

study location is available in Ref. [13]. The variation of surface meteorological parameters during the festival days shows insignificant day to day variability and without precipitation. Temperature varied between 13-30 ºC, relative humidity 26%-95% and wind speed was 1-3 m/s with wind direction mostly north-east. The average values of these meteorological parameters for the month of November were almost within the same range.

Surface O_3 measurement is carried out using a Teledyne T400 O_3 Analyzer. Its principle is based on absorption of UV radiation at 254 nm by O_3 molecules. The NO_x analyzer (T200 Teledyne API) works on the basis of the chemiluminescence effect produced by the oxidation of NO by O_3 molecules, which peaks at 630 nm. The T300 carbon monoxide analyzer (Teledyne API) is used to measure the CO concentration. The analyzer operates on the principle of infrared absorption at 4.7 μm, the vibration rotation band of CO. Measurement of SO_2 is carried out with T100 UV Fluorescence SO_2 Analyzer (Teledyne API). The T100 measures the fluorescence that occurs when SO_2 is excited by ultraviolet light in the wavelengths range 190-230 nm. BC concentration is measured using a seven channel Aethalometer (AE 3-ER, Magee Scientific) operated round the clock at a flow rate of 4 $L{\cdot}min^{-1}$. Attenuation of light beam at 880 nm through the aerosols deposited continuously on a quartz fiber filter tape is utilized to derive BC mass concentration. The temporal resolution of all the instruments is 5 minute. Details of the instrument and measurement uncertainties have been reported earlier [14].

3. Results and Discussion

To examine the impact of fireworks on O_3, NO_x, NO_2 and NO, CO, SO_2 and BC the concentrations of the species during the days of the festival are compared with their monthly average values (excluding the Diwali and post Diwali days), which is considered as the background concentration for each species. The diurnal variation of O_3, NO_x, NO and NO_2 concentrations are shown in Figs. 2a-2d. Surface level O_3 is not a direct product of fireworks, it increases due to rise in the level of precursor gases (NO_x, CO, CH_4, VOC_s, etc.), which are directly emitted from firework.

The daytime average values of O_3 were 22.9 ppb, 29 ppb and 25.4 ppb on Day 1 (13 November), Day 2 (14 November) post Diwali (15 November) days respectively. O_3 concentration during daytime showed increase on Day 2 of the Diwali, with a rise in the peak value by ~13 ppb compared to that on Day 1 of the Diwali and the monthly average background O_3. About 25% increase in daytime (06:00 to 15:00 h)

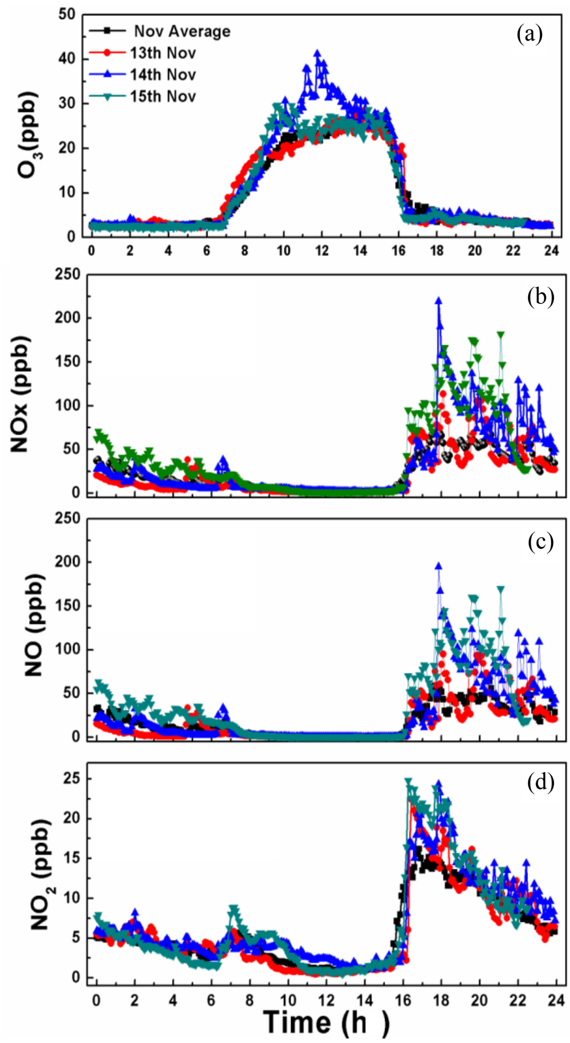

Fig. 2 Diurnal variation of surface (a) O_3, (b) NO_x, (c) NO and (d) NO_2 averaged for the month of November 2012, for Diwali days (Nov. 13-14, 2012) and post-Diwali day (Nov. 15, 2012).

average O_3 concentration was observed in Day 2 of the Diwali over the background level. This is attributed to the high level of precursor gases (e.g. NO_x and CO) in the atmosphere generated by the firework activities in the previous night. Nighttime O_3 level did not show any significant change. Similar variation of surface O_3 has been reported from New Delhi, India [15].

NO_x (NO and NO_2), SO_2, CO and BC are the primary products of burning; therefore, fireworks have immediate effect on the level of these species in the atmosphere. NO_x, NO and NO_2, all show continuous rise during the festival days than the background level. The concentrations of NO during the Diwali days in the peak hours (16:00-21:00 h) of firework activity and post Diwali are 44.9 ppb, 68.2 ppb and 92.7 ppb while the background concentration for the month of November was 39.0 ppb. Similarly NO_2 and NO_x concentrations were 13.5 ppb, 15.3 ppb, 16.9 ppb, 58.4 ppb, 83.4 ppb and 109.5 ppb, respectively. The backgroung concentrations of NO_2 and NO_x were 12.6 ppb and 51.7 ppb respectively. This shows that NO, NO_2 and NO_x concentrations gradually increased from the background level and reached the peak level of concentration on post-Diwali day with ~111%, ~34% and ~137% rise. This clearly depicts the accumulation of NO_x in the atmosphere from the Day 1 of Diwali to the post-Diwali day.

Figs. 3a-3c illustrates the diurnal variation of the CO, SO_2 and BC during Diwali, post-Diwali days and the background concentration for the month of November 2012. CO recorded an increase from the background level of 1.18 ppm to 1.42 ppm (~19%) on the post-Diwali day in the peak hours (16:00-21:00 h) of firework activity. On the other hand, SO_2 concentration showed significant increase of ~42% and ~63% on Day 1 and Day 2 of the Diwali respectively and then decreased on the post-Diwali day. Though fireworks activity subsided substantially Day 2 of the Diwali night the level of trace gases except SO_2 remain higher on post-Diwali day compared

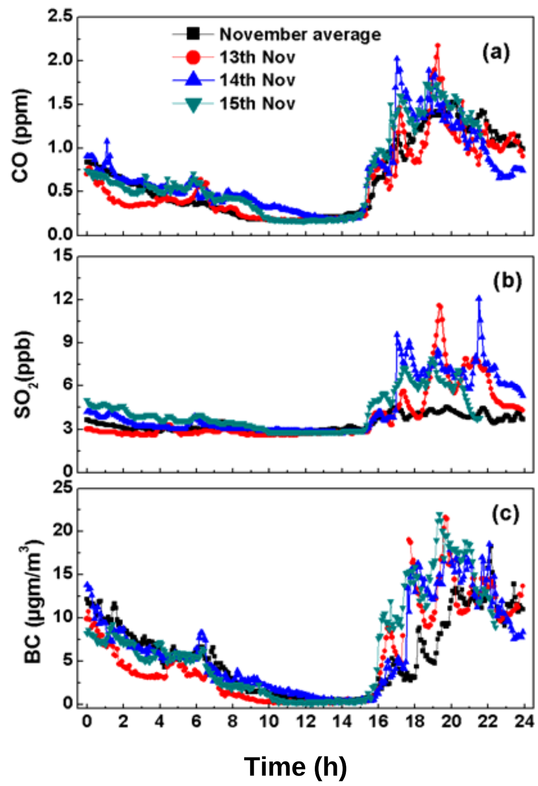

Fig. 3 Diurnal variation of surface (a) CO, (b) SO_2 and (c) BC averaged for the month of November 2012, for Diwali days (Nov. 13-14, 2012) and post-Diwali day (Nov. 15, 2012).

to Day 1 of the Diwali because of their accumulation in the atmosphere. The measured BC concentration showed similar day to day variability with a gradual increase from a background level of 6.67 μgm^{-3} to 11.3 μgm^{-3} and 11.03 μgm^{-3} on Day 1 and Day 2 of Diwali respectively and 14.6 μgm^{-3} on the post-Diwali day.

The diurnal variability of O_3 concentration shows daytime maxima and nighttime minima associated with photochemical production. On the other hand, NO_x, SO_2 and CO and BC show similar diurnal variation with primary peak in the night (18:00-22:00 h) apparently because of induction from fireworks apart from the regular boundary layer Dynamics. During night the boundary layer height gets reduced leading to confinement of the gases and particulate matter near the surface [14]. The firework activities thus have not disrupted the regular diurnal variability pattern, but resulted in large increase in concentrations of all the species during the peak hours of firework activity (16:00-21:00 h). Despite the firework activities the 24 h average concentrations of the gases were found to be below the national air quality standards of India. This ensures that the prevailing cleaner environment of the study location was not affected by the short time large induction of pollutants during the Diwali festival in the year 2012.

4. Conclusions

Significant rise in concentrations effect of fireworks on O_3, NO_x, SO_2, CO and BC concentrations have been observed during the peak hours of firework activity of the Diwali festival at Dibrugarh. The gradual increase in their concentrations from first day to the day after the festival has not affected the diurnal air quality of the location.

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