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Celebration-induced air quality over a tropical urban station, Pune, India

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ABSTRACT

In this paper, we studied the regional aerosol and air quality over an urban location, Pune, India during the period from 8 to 18 November 2012, encompassing a major Indian celebration, namely, Diwali Festival (12–14 November 2012) and also a clean (control) day (9 November 2012). A suit of ground–based measurements, employing solar radiometers (Microtops II and Cimel Sun–sky radiometer), Nephelometer, and satellite observations carried out over the study region have been applied for these investigations. The study revealed many interesting results which include (i) almost four–fold enhancement in AOD and fine mode dominated aerosol size distribution (ASD) during Diwali compared to clean day conditions; (ii) higher columnar water vapor (H_2O), nitrogen dioxide (NO_2), and lower ozone (O_3) during Diwali period; (iii) higher cooling at bottom (–117 W m^{-2}) and top of the atmosphere (–33 W m^{-2}) and warming (+82 W m^{-2}) in the atmosphere during the festival period, (iv) abundance of fine mode anthropogenic scattering particles associated with greater real part and smaller imaginary part of refractive index, and higher single scattering albedo, (v) higher backscattering coefficient revealing intrusion of more aerosol particles, higher depolarization ratio indicating particles of non–spherical nature, presence of water–phase particles, more polluted smoke and dust particles, (vi) greater attenuation and poor horizontal/vertical visibility, and (vii) dominance of urban industrial/biomass burning aerosols among other aerosol types. These results have been compared with concurrent satellite products and found to be consistent. The results have been further explained with local meteorology, back–trajectory analysis and satellite rapid response images.

Keywords: *Aerosols and gases, air quality, celebrations, radiative forcing, visibility*

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1. Introduction

Fireworks are an integral part of celebrations ranging from smaller scale local events such as birthdays or weddings, up to nationwide celebrations, often commemorating specific historical events, all over the world. Generally, two kinds of fireworks are used; one which can be exploded on ground, and the other one in the air. Nevertheless, the fine particulate matter generated by outdoor pyrotechnic display affects regional air quality, health, weather and climate. A variety of pyrotechnics employed in these works produce various visual, light, sound, gas and smoke effects. Such activities on diverse occasions in every country perturb the earth–atmosphere radiation balance due to additional anthropogenic activities in different ways. These celebrations can cause acute short–term air quality degradation (e.g., Drewnick et al., 2006) and long–term negative effects to human health (Bach et al., 1975; Vijayakumar and Devara, 2012a; Simha et al., 2013). Burning of fireworks release gaseous pollutants such as ozone, sulfur dioxide, nitrogen oxides (Attri et al., 2001; Ravindra et al., 2003) and suspended particulates with trace metals and organic compounds (Babu and Moorthy, 2001; Steinhauser et al., 2008; Vecchi et al., 2008; Barman et al., 2009; Thakur et al., 2010; Betha and Balasubramanian, 2013; Chatterjee et al., 2013) and reduction in visibility (Clark, 1997). The impacts of fireworks on aerosol size distribution (PM_{10}) and associated barium (Ba), which has direct bearing on human health (muscle cramps, heartbeat, asthma etc.), particle radiative and toxicological effects have been reported by Khaparde et al. (2012). Their results indicate that the Ba mass–size distribution depends on the intensity of the fireworks and distance between the burning of firecrackers from the monitoring site and hence suggest minimizing human exposure through public awareness programs.

The results, so far, available in the literature were mostly obtained from either point monitors or direct measuring equipment (samplers). Measurement of fireworks aerosols and precursor gases with high time resolution, using satellite and ground–based passive and/or active remote sensing techniques are very sparse. In this paper, we describe the simultaneous measurements of columnar aerosol optical, microphysical, radiative properties, ozone, nitrogen dioxide, water vapor from several ground–based, satellite remote sensing and in–situ techniques, and discuss the results with the help of local surface–level meteorological parameters, multi–level HYbrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) back–trajectory air mass analysis and satellite images.

2. About the Celebration

Diwali is one of the most fabulous festivals celebrated in India with joy and happiness. It is also known as "Festival of Lights", and is one of the popular cultural and religious festival during which millions of people light traditional lamps and ignite fireworks. Hand–held, ground–based, and airborne fireworks are performed during this occasion. It is usually celebrated in the month of October/November in every year. Diwali Festival is normally celebrated over a span of 5 days. The festive fever starts a few days prior to Diwali with people igniting fireworks, shopping for the celebrations and visiting each other and reaches a crescendo on the day of Diwali. A huge amount of crackers and sparklers are burnt mainly on the day of festival (Diwali day) and also on the day before (pre–Diwali day) and after (post–Diwali). During the year 2012, the main day of Diwali happened to be 13 November. In the present study, concurrent aerosol and pre–cursor gas observations from ground–based and satellite remote sensing have been carried out for about 11 days (8–18 November 2012) so as to have a few clean days unaffected by Diwali activity and a few around the main festival. The period covering one day prior and following the main Diwali day i.e. 12–14 November 2012 has been considered as festival period and the clean day 09 November 2012 is considered as control day outside the Diwali Festival period.

3. Experimental Station and Sampling Site

Pune [18º43´ N, 73º51´ E, 559 m above mean sea level (AMSL)], a densely populated, fast–growing urban city, about 100 km inland from the west coast of India was chosen as the monitoring site for the present study. The experimental station and sampling location are depicted in Figure 1. The environment in the immediate vicinity of the station is covered by several small and medium scale industries. Different air pollutants in significant quantities are released in the atmosphere by these industries and automobiles. Soil dust is the major source of aerosols present over the experimental station. Formation of aerosols in the accumulation–mode is considered to be due to gas–to–particle conversion (GPC) processes while the coarse–mode is attributed to wind–blown dust. More details about the experimental station and its meteorology can be found in the literature (Devara et al., 1994; Devara et al., 2002).

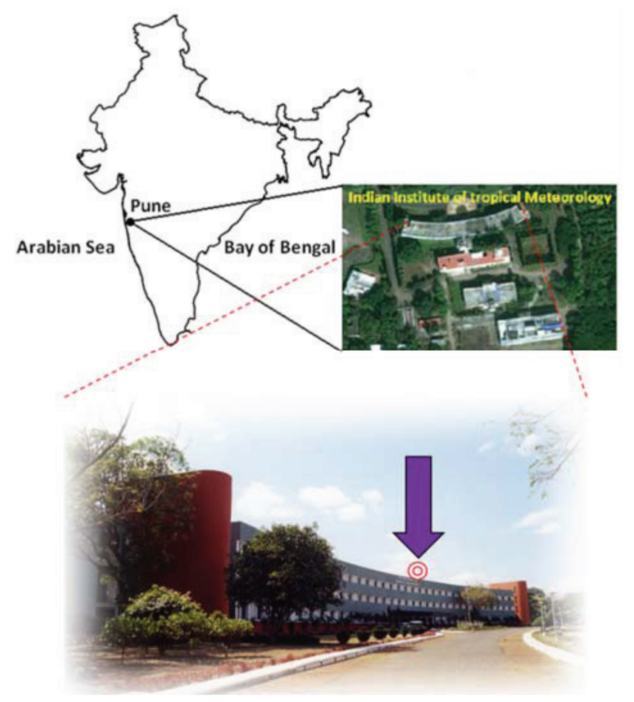

Figure 1. *Site map indicating the experimental location.*

The sampling location (indicated by a concentric double circle with downward arrow in Figure 1) was chosen on the terrace of the two–storied Institute's building, surrounded by hillocks as high as 760 m AMSL, forming a valley–like configuration. The terrace was chosen for making observations free from nearby tall buildings and trees. Moreover, this kind of sampling from terrace provides direct monitoring from the nearby houses having roof spaces which are generally used by the residents for firework display. The transport and dispersion of pollutants, particularly those in the lower levels of the atmosphere, are believed to be affected by the circulation processes associated with this complex terrain (Devara and Raj, 1991).

4. Instrumentation, Measurements and Methodology

A wide range of ground–based observations employing solar radiometers and in–situ instruments and concurrent satellite data were collected during the study period. Figure 2 displays the suit of instruments deployed in the study. These facilities include ground–based (i) solar radiometers [MICROprocessor–based Total Optical Spectrometer (MICROTOPS II of Solar Light Co. Inc., USA); Cimel Sun–sky Radiometer of Aerosol Robotic Network (AERONET) of NASA, USA; (ii) Integrating Multi–wavelength Nephelometer of Ecotech, Model Aurora–3000, Australia; (iii) Kipp and Zonen ventilated Pyranometer (Model CM21) down–welling short–wave and Eppley Model PIR Pyrgeometer down–welling long–wave radiation sensors; satellite–based [Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO); Moderate Resolution Imaging Spectrometer (MODIS) and Ozone Monitoring Instrument (OMI)]. In addition, an Automated Weather Station (AWS) of Dynalab, Model WDL–1002 (not shown in the figure) was used for recording ambient temperature and relative humidity variations in synchronization with the above observational facilities. All the above instruments have been described, in brief, in our earlier publications (Kumar et al., 2011 and references there in), hence they are not discussed here. All the above–mentioned instruments were operated simultaneously and the concurrent satellite data were acquired during 8–18 November 2012. The collected data were analyzed, as per the respective protocol, and the results are discussed in the following section.

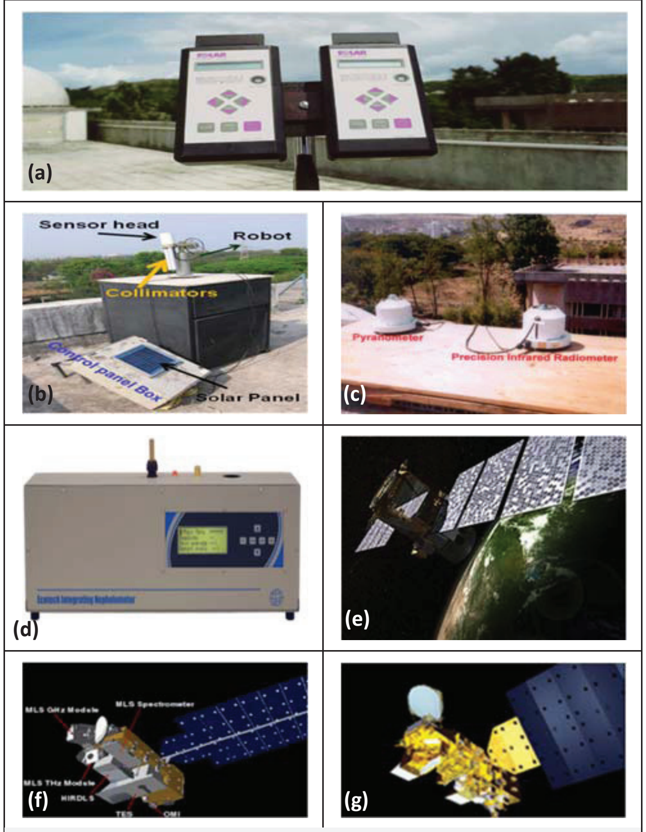

Figure 2. *Suit of instruments **(a)** Microtops II; **(b)** AERONET Sun–sky Radiometer; **(c)** Solar radiation sensors; **(d)** Nephelometer; **(e)** CALIPSO; **(f)** OMI and **(g)** MODIS) deployed in the study.*