Atmospheric Pollution Research 7 (2016) 25–30

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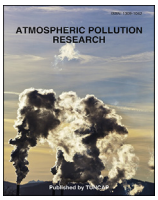
Atmospheric Pollution Research

journal homepage: http://www.journals.elsevier.com/locate/apr



Original article

Sensitivity of online coupled model to extreme pollution event over a mega city Delhi

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ARTICLE INFO

Article history:
Received 19 December 2014
Received in revised form
24 April 2015
Accepted 7 July 2015
Available online 23 October 2015

Keywords:
$PM_{2.5}$
Diwali
Extreme events
Weather
Chemistry

ABSTRACT

Sensitivity of interactive Weather-Chemistry model has been examined to predict the air quality (1 and 3 days in advance) of Indian mega city Delhi during two identical extreme events of Diwali in 2012 and 2013. Analysis is conducted 3 days prior to 3 days later of Diwali day for both events to verify the rapid changes in fine particulate matter ($PM_{2.5}$) due to widespread display of Diwali fireworks. The model successfully predicted the variability in $PM_{2.5}$ during 2012 for the entire period of analysis with reasonable accuracy. Although model performed reasonably well until Diwali day in 2013 but it was unable to simulate rapid built up of $PM_{2.5}$ (1500 μg^{-3} hourly average) during post Diwali day as it failed to capture unusual mid-night steep temperature gradient followed by a record lowering of boundary layer height. The predictability of the model and its limitation to micrometeorological processes are discussed in detail.

1. Introduction

Megacities are the engines of growing economies. India's capital New Delhi is a fast growing metropolitan city in terms of industrialization, constructions, population density and economic growth. This large development also has been a constant source of air pollution and climate change over the region. Delhi is ranked as the second populous city in the world as per the latest survey of Population Reference Bureau, USA (http://www.prb.org/). Delhi's degraded air quality is held responsible for about 18 600 premature deaths per year (TERI, 2001). Along with air pollution from regular sources, air quality in Delhi deteriorates due to fireworks as part of different festivals. Among different Indian festivals, Diwali is most widely celebrated festival once in every year across the country during which large amount of fireworks and fire crackers are used, causing serious air pollution. Generally Diwali falls during post-monsoon (either October or November) month. In this season, normal air pollution itself is high over Delhi due to colder temperature and lowering of boundary layer height. The fireworks associated with celebrations are reported to have enhanced the air pollution across different parts of the world. During international fireworks competition in Montréal, Canada, Joly et al. (2010) have reported $PM_{2.5}$ level up to 10 000 $\mu g\ m^{-3}$ over short time scale (roughly 1000 times to background level) at human breathing height and it was sustained at level of 1000 $\mu g\ m^{-3}$ over a fireworks display period (~45 min). Recent studies about the air-quality deterioration due to firework display during Diwali have been carried out in India (Ravindra et al., 2001, 2003; Barman et al., 2008; MoEF, 2009; Tiwari et al., 2012 Beig et al., 2013a). These studies reported that very high pollutant levels are registered on Diwali day.

Timely advanced air quality information on adverse pollution levels can assist the public to take precautions against the possible health hazards. Hence forecasting of different air pollutants are very important component in guiding public health during severe pollution events by issuing alerts for people to avoid polluted areas when the pollution levels exceeds critical limit. In this regard, Indian government has established national project namely System of Air Quality Forecasting And Research (SAFAR) to provide timely advanced air quality forecast. The SAFAR project utilizes a three dimensional air quality forecasting model (WRF-Chem) for issuing forecast for three and one day in advance. This project has been operational over Delhi since October 2010. Simulating the changes in micrometeorology during sudden extreme events has been a

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Peer review under responsibility of Turkish National Committee for Air Pollution Research and Control (TUNCAP).

http://dx.doi.org/10.1016/j.apr.2015.07.001

challenge in forecasting air quality. An accurate emission inventory with adequate meteorological information only can provide a forecast with minimal bias. However during extreme pollution events like Diwali, sometime meteorology plays a critical role which can suddenly change the air pollution scenario and put forecasting models on critical test. In this paper we discuss two identical extreme events during Diwali 2012 and 2013 to analyze the model performance in forecasting and attempt to discuss the factor responsible for model underperformance during Diwali 2013.

2. SAFAR-monitoring network and modeling set-up

2.1. SAFAR-monitoring network

Delhi is industrialized and urbanized megacity of India with an area of about 1483 km^2. SAFAR is a scientific project of Indian government which is piloted by GURME (Global Atmosphere Watch Urban Research Meteorology and Environment) program of WMO (World Meteorological Organization). Under SAFAR project a meso-network of several air quality and weather monitoring stations are established in the mega city area of Delhi (http://safar.tropmet.res.in/). In this work, we have used observations from three locations (Fig. 1) spread in different directions in Delhi spread in an area of 30 × 30 km and considered as representative of Delhi. Data used in the present study are obtained from ground based observations in Delhi (216 m ASL). These three stations had the most continuous pollutants dataset and a showed typical variation similar to all the other stations (other stations data not shown). The three stations, Delhi University (DU; 28.62°N, 77.19°E), India Meteorological Department-Lodhi Road (IMD-LD; 28.60°N, 77.27°E) and Indian Institute of Topical Meteorology-Delhi (IITM-D; 28.63°N, 77.22°E) were in almost continuous operation before, during and after event. IITM-D is located in a residential area, far from any major roads and point emission sources. DU is located about 500 m away from the main traffic road, while IMD-LD is located close to a large traffic intersection.

Data are spatially averaged for the homogeneity and robustness. It is found that spatial variability of $PM_{2.5}$ for identical periods is insignificant and hence consistency of the data is also established before averaging. Several gaseous (O_3, NO_x, CO etc.) and particulate matter (PM_{10} and $PM_{2.5}$) species are monitored in these stations. In this study we concentrate only on $PM_{2.5}$ (which has more or less same trend as PM_{10}). Measurements of $PM_{2.5}$ were made continuously with US-EPA approved online analyzer (BAM-1020; Met One Instruments, Inc, USA) which is based on the principal of beta ray

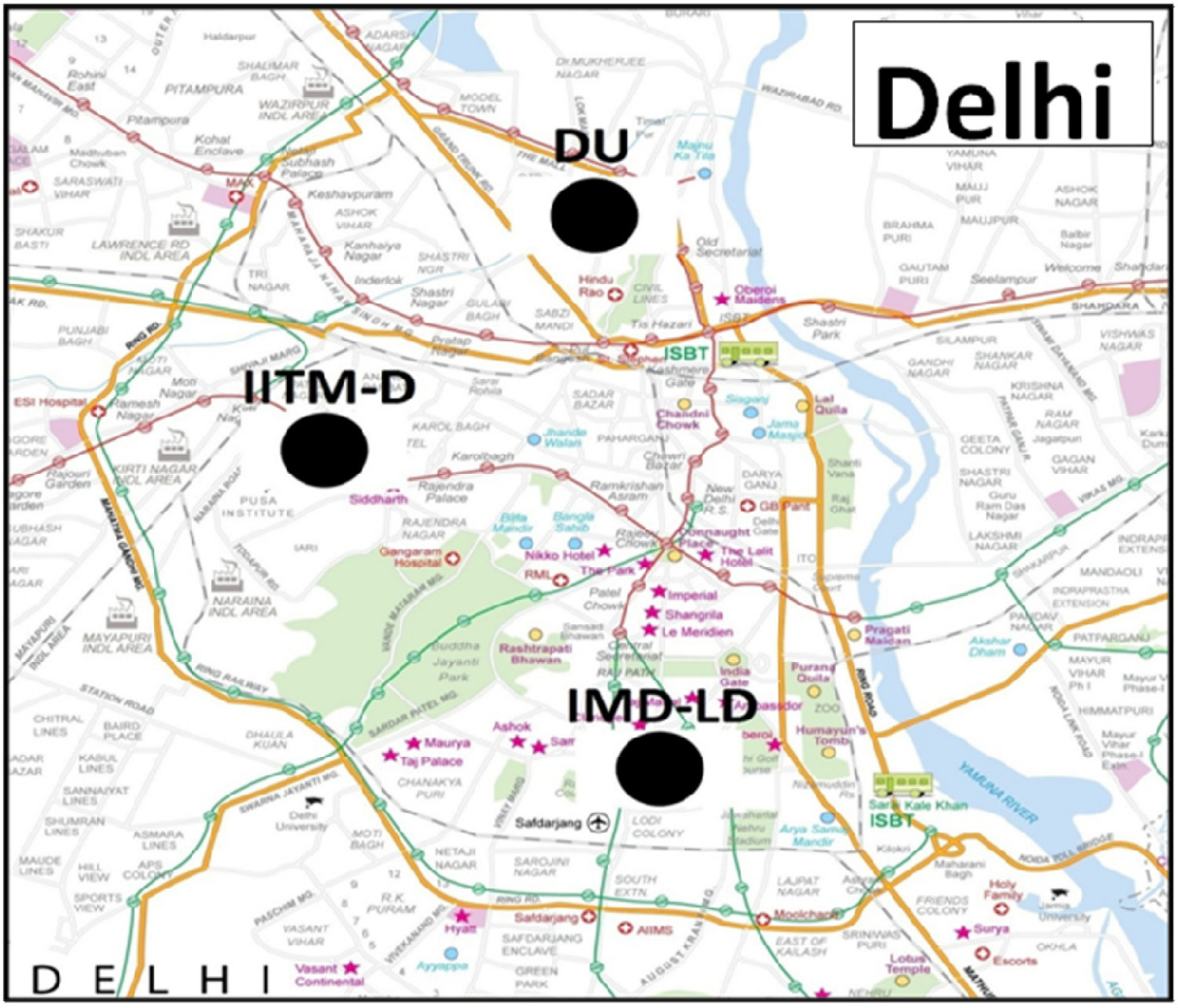

Fig. 1. Map of the three stations (Delhi University (DU), India Meteorological Department-Lodhi Road (IMD-LD) and Indian Institute of Tropical Meteorology-Delhi (IITM-D) that are representative of the Delhi and were selected for analysis in this study.