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Analysing temporal variability of particulate matter and possible contributing factors over Mahabaleshwar, a high-altitude station in Western Ghats, India

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ABSTRACT

Airborne particulate matter (PM) plays a vital role on climate change as well as human health. In the present study, temporal variability associated with mass concentrations of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ were analysed using ground observations from Mahabaleswar (1348 m AMSL, 17.56 ^{0}N, 73.4 ^{0}E), a high-altitude station in the Western Ghats, India from June 2012 to May 2013. Concentrations of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ showed strong diurnal, monthly, seasonal and weekday-weekend trends. The seasonal variation of $PM_{1.0}$ and $PM_{2.5}$ has showed highest concentrations during winter season compared to monsoon and pre-monsoon, but in the case of PM_{10} it showed highest concentrations in pre-monsoon season. Similarly, slightly higher PM concentrations were observed during weekends compared to weekdays. In addition, possible contributing factors to this temporal variability has been analysed based on the variation of secondary pollutants such as NO_2, SO_2, CO and O_3 and long range transport of dust.

1. Introduction

Atmospheric aerosols play an important role in climate change as well as air quality. In general, these airborne particulate matters (PM) can be classified into various size fractions such as PM_{10}, $PM_{2.5}$ and $PM_{1.0}$. PM_{10} are particles having an aerodynamic diameter of 10 µm and below, $PM_{2.5}$are particles having an aerodynamic diameter of 2.5 µm and below and lastly PM_1 are particles having an aerodynamic diameter of 1 µm and below. PM have great importance because of its adverse effects on the environment and human health (Raizenne et al., 1996; Houghton et al., 2001; Gauderman et al., 2004; Pope, 2004; Xiao and Liu, 2004; Cheung et al., 2005; Kampa and Castanas, 2008; Wang et al.,2008; Liu et al., 2014). Considering its impact on the environment, the high concentration of PM can degrade visibility (Zhao et al., 2013), affect global climate (Seinfeld and Pandis, 1998), change radiation budget by absorbing or scattering solar radiation (Ramanathan and Crutzen, 2003), etc. Apart from this, earlier reports also show its impact on human health such as respiratory and cardiovascular diseases (Schwartz et al., 2001; Berico et al., 1997; Dominici et al., 2005). Studies have also showed that these fine $PM_{2.5}$ particles penetrate more deeply into the human lungs and have more deleterious health impacts (Holgate et al., 1999). Thus, PM plays a vital role on climate change as well as human health.

Since these species are most critical pollutants in the majority of urban areas of the world (Brandt et al., 2013; Cassidy et al., 2014; Fridell et al., 2014; Kampa and Castanas, 2008). Several studies have been carried to understand the role of PM, its properties, sources, etc. It is reported that sources of PM can be anthropogenic as well as natural. Natural sources include sea spray, volcanic eruption, biological particles such as pollen, bacteria, fungal spores, dust from deserts, grassland fire or forest fire, etc. On the other hand, the anthropogenic sources are emissions from vehicle, industry, domestic heating or households. Many studies have been carried out worldwide on PM characterization which includes studies from Indian subcontinent also such as Trivandrum (Pillai et al., 2002), Delhi (Tiwari et al., 2009, 2012), Udaipur (Yadav et al., 2014), Agra (Satsangi et al., 2011), Sinhagad –Pune (Satsangi et al., 2014), Raipur (Dhananjay et al., 2013), Ahmedabad (Bhaskar and Vikram, 2010; Sudheer et al., 2015), Anantapur (Balakrishnaiah et al., 2011), Lucknow (Verma et al., 2014) etc. It is known that Indian subcontinent mainly tropical and subtropical regions experiences extreme temperatures, rainfall and relative humidity (Bhaskar and Vikram, 2010). These atmospheric conditions can introduce large variability in aerosol characteristics spatial and temporal scales over India

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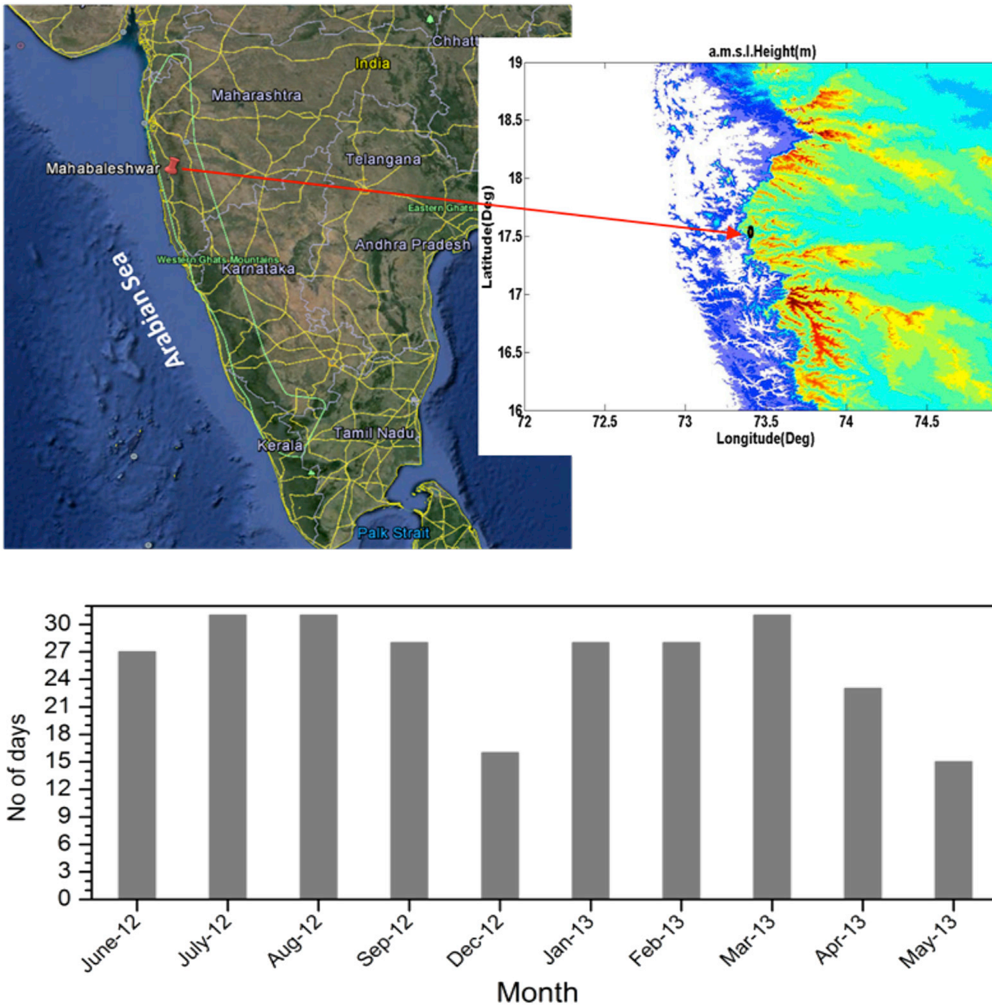

Fig. 1. (a) Google Earth view of the study site (Pinned in red) along with topography plot and (b) bar plot showing month wise PM data availability. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Ramachandran, 2007).

From this literature survey, it is clear that studies on PM from high altitude sites of Indian region are sparse. Thus in the present study for the first time, we are trying to attain a detailed understanding of mass variability of PM over Mahabaleshwar, a high altitude site in the Western Ghats. The objective of the work has been divided into two sections in which first temporal variability (monthly, diurnal, seasonal and weekend-weekday trends) of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ has been analysed using ground based observations available from High Altitude Cloud Physics Laboratory (HACPL). Secondly, possible factors contributing (the role of pollutants and effect of dust storm) to PM variability has been verified using satellite observations and HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectories) air-mass back trajectories.

2. Data used

2.1. Environmental Dust Monitor

The measuring device for airborne dust is a stationary instrument Environmental Dust Monitor (EDM 180) from GRIMM Aerosol Technik, which has been designed for the continuous measurement of airborne dust and its particle size distribution (http://www.dustmonitor.com/). The measured values will be saved as mass concentration in the unit μg m^{-3} and distinguished according to the fractions PM_{10}, $PM_{2.5}$, and $PM_{1.0}$. The measuring principle is the scattering light measurement of the single particles, where a semiconductor laser serves as light source. When particles cross the laser beam they scatter light. The scattered signal is then transferred into a diode and then classified into 31 different size channels after an adequate amplification. This enables a size determination of the particles and also let realize a weighting curve. The rinsing air flow rate is 0.3–0.5 l min^{-1} and the mass concentration range is from 0.1 to 6000 μg m^{-3}. The data is obtained for every 5 min. For a precise and reproducible particle counting and particle sizing the accurate sampling volume of 1.2 L/minute is analyzed. We have used PM data from June 2012 to May 2013 in which the observation for October and November is not available. Fig. 1 (b) represents the number of days of observations for each month.

2.2. Supporting data for source extraction

We have used several supporting observations for the source extraction of PM. First, role of gaseous pollutants such as NO_2, SO_2, CO and O_3 have been analysed using satellite observations. NO_2 and SO_2 have been extracted from OMI (Ozone Monitoring Instrument) satellite. This provides daily observations of both with a spatial resolution of 0.25 deg × 0.25 deg. For the present study vertical column density of NO_2 and SO_2 (Planetary boundary layer) has been used. Ozone (O_3) measurement data have been obtained from AIRS (Atmospheric Infrared Sounder) instrument. This provides monthly observations with a spatial resolution of 1.0 deg × 1.0 deg. More details related to data at http://giovanni.sci.gsfc.nasa.gov/or https://earthdata.nasa.gov/discipline/atmosphere.