Atmospheric Research 169 (2016) 65–72

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

# Potential source identification for aerosol concentrations over a site in Northwestern India

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ARTICLE INFO

Article history:
Received 27 July 2015
Received in revised form 7 September 2015
Accepted 22 September 2015
Available online 3 October 2015

Keywords:
Aerosol number concentration
Size distribution
AOT
PSCF

ABSTRACT

The collocated measurements of aerosols size distribution (ASD) and aerosol optical thickness (AOT) are analyzed simultaneously using Grimm aerosol spectrometer and MICROTOP II Sunphotometer over Jaipur, capital of Rajasthan in India. The contrast temperature characteristics during winter and summer seasons of year 2011 are investigated in the present study. The total aerosol number concentration (TANC, 0.3–20 μm) during winter season was observed higher than in summer time and it was dominated by fine aerosol number concentration (FANC < 2 μm). Particles smaller than 0.8 μm (at aerodynamic size) constitute ~99% of all particles in winter and ~90% of particles in summer season. However, particles greater than 2 μm contribute ~3% and ~0.2% in summer and winter seasons respectively. The aerosols optical thickness shows nearly similar AOT values during summer and winter but corresponding low Angstrom Exponent (AE) values during summer than winter, respectively. In this work, Potential Source Contribution Function (PSCF) analysis is applied to identify locations of sources that influenced concentrations of aerosols over study area in two different seasons. PSCF analysis shows that the dust particles from Thar Desert contribute significantly to the coarse aerosol number concentration (CANC). Higher values of the PSCF in north from Jaipur showed the industrial areas in northern India to be the likely sources of fine particles. The variation in size distribution of aerosols during two seasons is clearly reflected in the log normal size distribution curves. The log normal size distribution curves reveals that the particle size less than 0.8 μm is the key contributor in winter for higher ANC.



## 1. Introduction

Aerosols are a major component of our environment and play an important role in the climate of the Earth-atmosphere system by means of their direct and indirect impact on climate (Schwartz et al., 1995). Atmospheric aerosol particles are one of the most variable components of the Earth's atmosphere and influence the energy budget and climate (Remer et al., 2005).

Aerosol number concentration and size distribution plays a crucial role in shaping Earth's radiation budget by scattering and absorption of sunlight in atmosphere. Scattering and absorption coefficient is an important parameter which strongly depends on particle's physical and chemical property. One of the key physical parameters of aerosols is the number size distribution, and especially for the climate effects, the size distribution in the sub-micron range. Most of the monitoring networks across the world measures $PM_{10}$ and $PM_{2.5}$ (mass of particulate matter smaller than 10 and 2.5 μm in aerodynamic diameter, respectively). Measurement of aerosol particle number size distribution was carried out in many cities of the world i.e. Birmingham (Harrison et al., 1999), Atlanta (Woo et al., 2001), Helsinki (Buzorius et al., 1999; Hussein et al., 2004), Leipzig (Wehner and Wiedensohler, 2003), Pittsburgh (Stanier et al., 2004), Beijing (Wu et al., 2008). These studies showed the seasonal variation with low aerosol number concentration in summer while high during winter.

In India the majority of observations are from coastal or urban locations. A high particulate matter concentration (Bhanarkar et al., 2002; Mitra and Sharma, 2002; Gajananda et al., 2005; Chatterjee et al., 2010) has been reported from Indian cities. Kumar and Sarin (2009) reported mass concentrations of fine particulate matter less than or equal to 2.5 μm ($PM_{2.5}$) and coarse ($PM_{10-2.5}$) mode aerosols to vary from 1.6 to 46.1 and 2.3 to 102 μg/m$^3$, respectively over the annual seasonal cycle during 2007 at a high-altitude site (Mt. Abu) in a semi-arid region. The aerosol number concentration during fireworks and vehicular emission is carried out by researcher in India (Singh et al., 2003; Kulshrestha et al., 2004; Pant et al., 2006; Pant et al., 2010; Majumdar and Nema, 2011; Sharma et al., 2011; Prakash et al., 2013; Saha et al., 2014; etc.).

However, at large, the semi-arid region over India there is a very limited number of long-term datasets of sub-micron aerosol particle size distributions. Even from the Indo gangetic basin, where several

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http://dx.doi.org/10.1016/j.atmosres.2015.09.022
0169-8095/

intensive measurement campaigns have been carried out during recent years, no size distribution measurements that cover a full year have been published (see, for example, the review by Lawrence and Lelieveld (2010)). Most probably it is the first study of its kind to understand the aerosol number concentration behavior and its origin during two different seasons over this region.

The possible sources of aerosols on a regional scale over India have only recently received attention. In the present study, we identify potential source regions of the factors during the event using Potential Source Contribution Function (PSCF), and combine it with particle number concentration for source identification. Several observations of aerosol concentrations have been made over Northwestern India (Verma et al., 2013; Payra et al., 2015). The general trend over the site during pre-monsoon season was high AOT and low AE values and vice-versa in winter (Payra et al., 2013). The in-situ measurements for 2011 have also shown the similar trends of AOT and AE. However, AOT and AE were a little bit higher and lower than the mentioned respective values. In-situ measurements are thus important especially at strategic places like Jaipur which can help determine the regional radiation budget over a semi-arid region.

In continuation to above, in this paper the concentration of different sized particles, during two contrasting seasons i.e. winter and summer time are studied over Jaipur, Northwestern India. Specially, the characteristics of modes appearing in measured particle size distributions in combination with MICROTOP II sunphotometer data are investigated. The purpose of this study is to determine the characteristic of aerosol size distribution at Jaipur during two extreme seasons by examining the simultaneously measured size-separated number concentrations.

## 2. Instrumentation and data used

### 2.1. Site description

Jaipur, the study area, lies in desert belt receiving most of the rain during late summer months. The measurement site is located about 6 km to east from the Jaipur city centre. The climate of the region has three distinct seasons; summer (April–June), monsoon (July–September) and harsh winter (December–January). Fig. 1 shows meteorological conditions of site retrieved from National Center for Environmental Prediction (NCEP)—National Center for Atmospheric Research (NCAR) reanalysis data. The rainfall values used in Fig. 1 were taken from the Department of Water Resource, Government of Rajasthan; (http://waterresources.rajasthan.gov.in/Daily_Rainfall_Data/Rainfall_Index.htm). The average temperature during 2011 at Jaipur increases from 14.4 °C in January to become maximum at 35.2 °C in May and thereafter it fell to 17.5 °C in December. Wind speed at Jaipur gradually seems to decrease from 11.8 km/h in May to 3.8 km/h in November. The wind direction at Jaipur shows its flow mostly from south-west (from the Thar Desert area of India). The relative humidity shows an increase

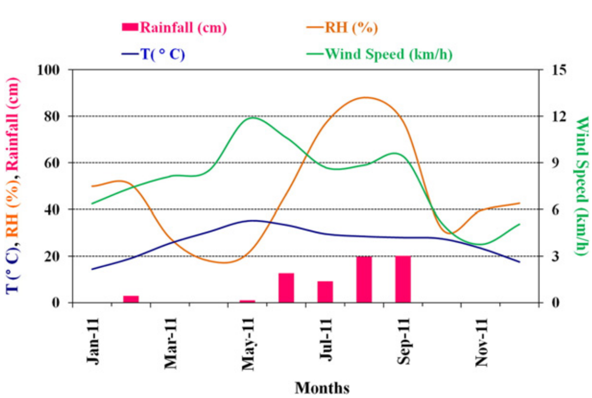


**Fig. 1.** Monthly variation of meteorological parameter over study location.

from ~18% in April to ~88% in August. Thereafter RH again decreases to ~32% in October showing thereby that summer is less humid than monsoon but more humid than the onset of winter season.

### 2.2. Instruments used

The ground-based aerosol measurements have been carried out at Birla Institute of Technology (BIT), Jaipur, India (26.90 N, 75.80 E and 450 m altitude from mean sea level) using handheld MICROTOPS II sun-photometer from morning to evening during April to December 2011 on clear sky days. The MICROTOP II (Solar Light Company, USA) is a hand-held multi-band sun-photometer capable of measuring the AOT by direct solar irradiance in each band. MICROTOP II provides aerosol optical thickness (AOT) and columnar water vapor from instantaneous measurement at five channels with full field of view of 2.5°. The instrument measures the intensity of direct solar irradiance at five narrow-band spectral channels centered at 440, 500, 675, 870 and 936 nm and gives corresponding AOT. Sun photometers are specialized narrow field-of-view radiometers designed to measure solar irradiance (Shaw, 1983). The handheld sun-photometer measures attenuation of the direct sunlight as it passes through the atmosphere. As instrument's aperture is small, sun-photometer measure light intensity is usually not influenced by atmospheric scattering, at least for moderate AOT value.

Aerosol number concentration data is retrieved from Grimm Aerosol Spectrometer i.e. Grimm model 1.108 portable aerosol spectrometers (Grimm Aerosol Technik GmbH, Germany) over the site location. For observations at Jaipur, Grimm is configured in particle count mode (particle/l) in 15 different size channels at 15-min time intervals. The Grimm Aerosol Spectrometer measures the particle number concentrations in an optical size of 0.3–20 μm with 15 differently size ranges (Mohan and Payra, 2006). The Grimm Aerosol Spectrometer measures the number of particles per unit volume of air using light-scattering technology, in which a semiconductor laser serves as light source. The machine uses an internal air-sampling pump (1.2 l/min) for single particle count. The detail information of this monitor can be found in Cheng and Lin (2010).

### 2.3. Potential Source Contribution Function (PSCF)

Receptor modeling approaches such as Potential Source Contribution Function (PSCF) is an effective tool in source identification of urban and regional-scale pollution. In this work, Potential Source Contribution Function (PSCF) analysis is applied to identify locations of sources that influenced concentrations of aerosols over study area in two different seasons. The PSCF is a conditional probability function that describes the spatial distribution of probable source locations of the atmospheric pollutants in a geophysical region. PSCF derives the information on the various sources of aerosols during different seasons and varying contribution from different source regions.

PSCF explicitly incorporate the airborne concentration data and air parcel backward trajectories and estimates the conditional probability function that an air parcel with a specified level of a pollutant concentration arrived at a receptor site after having passed through a specific region (Cheng et al., 1993; Gao et al., 1996; Kindap et al., 2006; Mehta et al., 2009; Niemi et al., 2009). The PSCF in an *ij*-th grid cell of a geophysical region is defined as:

$$PSCF_{ij} = \frac{P(B_{ij})}{P(A_{ij})} \quad (1)$$

where $P(B_{ij})$ is the probability of occurrence an event if the trajectories segment endpoints associated with the concentrations higher than a pre-specified threshold (criteria) value arrived in the *ij*-th grid cell, and $P(A_{ij})$ is the probability of an event of all trajectories segment endpoints passed through the same *ij*-th grid cell in that region. Due to a higher degree of uncertainty associated with the grid cells with small