



Multi-site characterization of tropical aerosols: Implications for regional radiative forcing

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ABSTRACT

A land campaign, as a part of the Indian Space Research Organization-Geosphere Biosphere Program (ISRO-GBP), has been organized using a suit of instruments like AERONET (Aerosol Robotic Network) Sun/Sky sunphotometer, Microtops-II (MICROprocessor-controlled Total Ozone Portable Spectrometer), short-wave pyranometer from December 1, 2006 to April 30, 2007, over five locations (Ahmedabad, Pune, Sinhgad, Trivandrum and Gadanki) representing different environments. The dominance of different aerosol types such as biomass burning, urban/industrial pollution, marine origin and desert-dust particles is expected at these five sites. In all locations, significant day-to-day variability in AOD and Ångström exponent is observed. The Ångström exponent exhibits its lowest values over semi-arid region (Ahmedabad) 0.4–0.7, while it is around 1.8 at rural site (Gadanki). The retrieved volume size distributions for Pune, Ahmedabad and Trivandrum are found to be bimodal with varying concentration of each mode. Interesting feature of this observation is, very low coarse-mode volume concentration observed at Trivandrum even though observations were made about 300 m from the coast. The synergy of results from these complementary measurements is reflected in the computed regional aerosol radiative forcing and heating rates. We have used a radiative transfer model (SBDART) to examine the variations of aerosol direct radiative effect (ADRE) and heating rates to give an overall estimation of the effect on climate. The ADRE, over different measurement sites, at short wavelength is found to be negative at the surface in the range of -18 to -59 W m^{-2} , and TOA forcing values varied from $+0.9$ to -8 W m^{-2} .

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1. Introduction

The importance of aerosol in climatic perturbations stems from its heterogeneous nature due largely to the multitude of sources, its volatility and mobility. Many studies regarding spatial and temporal variations of atmospheric aerosols have been carried out (e.g. Holben et al., 2001; Devara et al., 2002; Dubovik et al., 2002; Kim et al., 2004; Eck et al., 2005, 2010; Kambezidis and Kaskaoutis, 2008), but considerable uncertainties still exist due to the large variabilities and ensuing poor understanding of aerosol properties (IPCC, 2001, 2007).

Aerosols are not well-mixed in the atmosphere so their properties, such as the optical depth (AOD), the Ångström exponent (α), single scattering albedo (SSA) and asymmetry factor (g) depend on geographic scenarios that govern the emission, transport, atmospheric transformation (Kumar et al., 2011) and removal of aerosol particles. Given the short lifetime of aerosol particles, their properties vary with time and from one region to another like urban (Dubovik et al., 2002), desert (Eck et al., 2008), forest (Schafer et al., 2008) and coastal (Smirnov et al., 2003) sites. Understanding local effects of aerosols would improve the current knowledge about aerosols around the world and would be useful in integrating global data sets (IPCC, 2007).

Ground-based remote sensing of aerosols is ideal for the reliable and continuous derivation of aerosol properties in key locations around the world (Holben et al., 2001). An advantage of this ground-based perspective is that the retrievals are representative for the entire vertical column with no height

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dependence which is useful for radiative effects estimation (Yu et al., 2006). Ground-based measurements of a variety of optical aerosol characteristics are necessary for validating aerosol products obtained from various satellite sensors (Kleidman et al., 2005; Li et al., 2007; Badarinath et al., 2011). Recent research (IPCC, 2007; Myhre, 2009) has emphasized that assessments of aerosol effects on climate require globally distributed information not just on aerosol amount, but also on aerosol characteristics such as size, composition and optical properties, especially radiation absorption.

While the retrieval of the spatial and temporal distributions of aerosol on a global scale is a task for satellite measurements, the increased emphasis on satellite aerosol retrievals has created the need for accurate ground-based, ground-truth aerosol measurements with which to validate satellite aerosol retrievals over land and ocean (Remer et al., 2005; Smirnov et al., 2006). Ground-based aerosol remote sensing does not provide global coverage, however, its wide angular and spectral measurements of solar and sky radiance is best suited to reliably and continuously derive the detailed aerosol optical properties in key locations. In spite of high temporal and spatial variability, there are aerosol types with distinctly different optical properties. Comprehensive knowledge of the optical properties of aerosol types is needed to minimize the uncertainty of aerosol radiative forcing computation. Additionally, refining aerosol optical models is important for improving the accuracy of satellite retrieval algorithms that rely on assumptions of the optical properties of different aerosol types (Remer et al., 2005; Kahn et al., 2005).

In this communication, we report the results obtained through a six-month-long campaign, the daily aerosol optical depths measured, the multispectral Ångström parameter (or wavelength exponent), single scattering albedo, volume size distribution, asymmetry factor and the retrieved columnar water vapor at five selected sites representing aerosols from biomass burning, desert dust, coastal, background, and anthropogenic/urban sources. In addition, a radiative transfer model is used to examine the variations of ADRE (DRE) at the top (TOA) and bottom of atmosphere (BOA).

2. Campaign sites, meteorology and datasets

2.1. Campaign sites

The multisite campaign was conceived to compare the columnar aerosol characteristics noticed over urban with other locations such as high-altitude, coastal, rural and urban-arid regions in India (Fig. 1). The main aim was to use same Cimel Sun/Sky sunphotometer to observe the columnar aerosol parameters over these locations, Pune being the anchoring site; it was made sure that before embarking to a new location a spell of observation should be carried at Pune. The campaign was initiated on December 01, 2006 at IITM (Indian Institute of Tropical Meteorology) campus. The details related to locations, campaign period, measurement days and instruments used are presented in Table 1. In the following paragraph a brief description about the sites is given, more details can be found in the concerned references cited therein.

The observation site, the IITM campus is located almost on the western edge of a fast-growing urban center, Pune [18.53° N, 73.8° E, 559 m amsl (above mean sea level)], India. It is

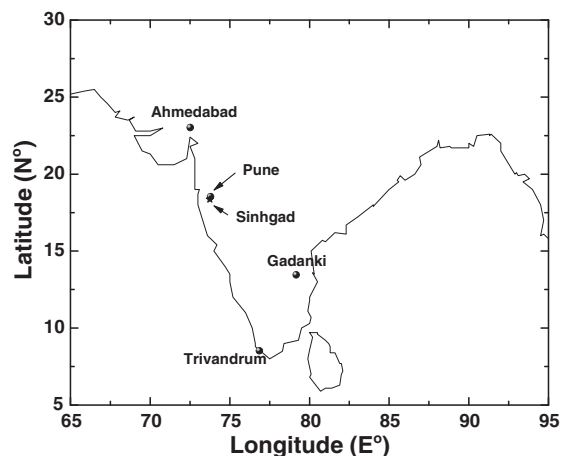


Fig. 1. A map showing the measurement locations.

situated about 100 km inland on the west coast of India, on the lee-side of the Western Ghats. Pune has witnessed a substantial growth in terms of population (Human ~ more than 4 million and vehicular ~ 2 million in 2010), and also industrial installations due to rapid urbanization. The industrial growth, increasing usage of fossil fuel and other sources has led to increase in aerosol load in the recent years. Aerosols over Pune have typical urban characteristics. They are a mix of anthropogenic and natural origin. The most variable being the natural one due to seasonal shifts in wind pattern. More details about this site, meteorology and possible aerosol type present over the station can be found in Devara et al. (2005); Safai et al. (2010); Kumar et al. (2011). The annual rainfall over Pune is around 700 mm per year, ~80% of which happens in monsoon (June to September) season.

Surface meteorological measurements show (Fig. 2a) that for Pune the day's maximum temperature was highest in the month

Table 1

Details of the locations, instruments used, campaign period and measurement days during each campaign.

Station name	Campaign period	Measurement days	Instruments used
Pune (IITM) (18.53° N, 73.8° E, 559 m amsl)	1–22, 31 Dec 2006 1 Jan–26 Jan 2007 6 Feb–18 Feb 2007 5 Mar–6 Apr 2007	1–15, 17–20, 31 Dec 2006 1–22 Jan, 26 Jan 6–8, 10–11, 14–16, 18 Feb 5–10, 14–21, 23–30 Mar, 3–6 Apr	Cimel Sun/Sky radiometer, pyranometer
Sinhgad (18.36° N, 73.75° E, 1450 m amsl)	22–30 Dec 2006 27 Jan–5 Feb 2007	22, 25–30 Dec 2–5 Feb	Cimel Sun/Sky radiometer, pyranometer
Trivandrum (TERLS/SPL) (8.53° N, 76.86° E, 3 m amsl)	21 Feb–2 Mar 2007	22, 23, 24, 28 Feb, 1 Mar	Cimel Sun/Sky radiometer
Ahmedabad (SAC) (23.02° N, 72.52° E, 55 m amsl)	9 Apr–16 Apr 2007	All	Cimel Sun/Sky radiometer, pyranometer
Gadanki (NARL) (13.45° N, 79.17° E, 340 m amsl)	22 Apr–3 May 2007	25, 27 and 28 Apr	Microtops-II, pyranometer

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