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In-situ measurements of atmospheric aerosols by using Integrating Nephelometer over a semi-arid station, southern India

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HIGHLIGHTS

- The σ_{sp}^{550} is found to be 7.8%, reduction from weekdays to weekends.
- The low backscattering ratio is observed during the post-monsoon and higher in the summer.
- The boundary layer height is negatively correlated ($R = -0.68$) with σ_{sp}^{550}.
- A significant +ve correlation has been observed between σ_{sp}^{550} and BC.
- RH versus σ_{sp}^{550} for ambient aerosols shows positive relation where as WS and AT is showed reciprocally.

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ABSTRACT

Continuous real-time measurements of aerosol scattering properties were investigated at Anantapur (14° 62′ N, 77° 65′ E, 331 m asl), a semi-arid region in southern India for the period of January 2011–December 2011, using a three-wavelength Integrating Nephelometer. Aerosols scattering properties like the scattering coefficient (σ_{sp}), backscattering coefficient (σ_{bsp}), scattering Ångstrom exponent (Å), backscattering ratio (b_λ) and asymmetry parameter (g_λ) were measured for the period of study. The average values of (±standard deviation) σ_{sp}, σ_{bsp} at 550 nm (σ_{sp}^{550}, σ_{bsp}^{550}) and $Å_{(700/450)}$ were found to be 97 (±9.2) M m^{-1} and 14 (±0.93) M m^{-1} and 1.02 (±0.3), respectively. The estimated average values of b_λ and g_λ at 550 nm from σ_{sp}^{550} and σ_{bsp}^{550} were 0.13 (±0.09) and 0.59 (±0.1), respectively. The maximum asymmetry parameter at 550 nm was found to be 0.63 ± 0.01 in the month of October and minimum (0.52 ± 0.03) during March, which shows the opposite trend with backscattering ratio. Significant correlation coefficients were noticed between different aerosol optical properties. The highest values of σ_{sp}^{550} were observed during weekdays whereas low values during weekends. Scattering Ångstrom exponent for the summer and winter seasons has been consistent with the input of fine mode particles from anthropogenic origin.

1. Introduction

Atmospheric aerosol particles are one of the most variable components of the Earth's atmosphere and are known to influence the energy budget and climate. Aerosol particles affect the Earth's radiative balance and climate directly by absorbing and scattering of solar radiation (Haywood and Shine, 1997; Foster et al., 2007) and indirectly supports for cloud condensation and thus changing the microphysical properties of clouds (Kaufman et al., 2005; Foster et al., 2007). The magnitude and sign of the aerosol forcing effect are determined, in part or by both the horizontal and vertical distribution of the aerosol particles (Haywood and Ramaswamy, 1998). Also, aerosol particles play a major role in atmosphere chemistry and so affect the densities of other minor atmospheric constituents like ozone (Schwartz et al., 1995). Furthermore, aerosol particles have been implicated in human health effects (Dockery and Pope, 1996) and visibility reduction in urban and regional areas (Horvath, 1995). Knowledge of the light scattering properties of atmospheric aerosol particles is of vital importance in estimating the radiative forcing of climate and in

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global radiation budget studies. Uncertainties in the global aerosol direct and indirect effects are nearly the same or twice as much as the magnitude of the effect itself as estimated by the International Panel on Climate Change (IPCC) in its 4th assessment report (IPCC, 2007). The optical properties of aerosols are related to both their chemical composition and particle size distributions. The atmospheric aerosols in different regions consist of varying composition and size mode, which lead to different radiative impacts on regional climate.

The backscattering ratio, is the ratio of light scattered in the backward hemisphere to the total light scattered by a particle or group of particles. The backscattering ratio has also been used to infer the particle properties *in situ*. The backscattering ratio is found to be used to derive the slope of the particle size distribution and also provides an estimate of the bulk refractive index of particles in the atmosphere. Asymmetric parameter (g) is another parameter which also depends both on the size distribution and composition of aerosol particles and also a function of the relative humidity. Radiative transfer computations use parameterizations of the angular distributions of scattered light or the aerosol phase functions of different aerosol distributions. Many workers have been dedicated to study the aerosol optical properties and their variation at different locations worldwide (Bodhaine and Dutton, 1993; Bodhaine, 1996; Parameswaran et al., 1998; Bergin et al., 2001; Formenti et al., 2002; Colland Coen et al., 2007; Lyamani et al., 2008; Andreae et al., 2008; Jung et al., 2009; Pereira et al., 2011).

In this paper, we report the intensive measurements of aerosol optical properties such as aerosol scattering and Backscattering coefficients over a semi-arid region in southern India, and then analyzed their diurnal variation. Secondly, correlation between aerosol optical parameters was investigated by scattered plots. The influence of meteorological parameters on the aerosol scattering properties has also been analyzed. This study helps in understanding the aerosol scattering effects in the context of regional and global climate change.

2. Site description

Anantapur district in Rayalaseema region (14°62′ N, 77°65′ E) of Andhra Pradesh is geographically situated in a semi-arid zone and occupies the second place to Rajasthan. Anantapur district is the driest part of the state of Andhra Pradesh. Nearly 85 percent of the population is affected by drought in this district, due to low rainfall, high temperature and severe dry winds during monsoon periods. The observation site, Sri Krishnadevaraya University (SKU: 14°62′ N, 77°65′ E and 331 m above sea level) is situated at about 12 km away from the southern edge of the Anantapur town (Fig. 1). The study area is also at a relatively short distance from two national highways (NH 7 and NH 205) and the town area is situated between north and southwest side of the sampling site (Balakrishnaiah et al., 2011a). Within a 50 km radius, this region is surrounded by a number of cement plants, limekilns, brick slab polishing industries and stone crushing machines. Gold mines are situated in southwest region about 40 km away from the observational site. These industries release large quantities of particulate matter into the atmosphere every day. Being far away from east and west coasts, this district is deprived of the full benefits of both the monsoons and consequently droughts are frequently experienced here. It receives the lowest average rainfall of about 450 mm compared to the Andhra Pradesh state average of about 900 mm. During April, June and November months the mean rainfall varies from 10 mm to 50 mm. Clear sky days and full sunshine prevails in the remaining months in this region. Anantapur town and its surroundings experience strong winds (>5 m s^{-1}) during July, August and September months. During October, wind patterns start shifting in direction from southwest to northeast. Most of the winds are prevailing from south-westerly direction during the total observation period. The continental conditions prevailing at this site are responsible for large seasonal temperature differences. On other hand, forest fires and transported dust are the other factors responsible for additional source of aerosol particulates (Badarinath et al., 2009, 2010). During winter, domestic heating (mainly wood, charcoal and diesel central heating) contributes more pollutants to the atmosphere (Kumar et al., 2011).

3. Instrumentation

The Integrating Nephelometer TSI model 3563 has been used to measure the total scattering (7°–170° angular integration) and the hemispheric backscattering (90°–170^0) coefficients at three visible wavelengths (450, 550 and 700 nm each with a bandwidth of 50 nm). The instrument is kept on the top floor of a three stored building (12 m). An inverted funnel with screws fitted at the entrance of the instrument to avoid the dust, rain water and insects entering into the system. This instrument draws the ambient air through a stainless steel tubing (Diameter = 3.2 cm and Length = 1.8 m) inlet at a flow rate of 20 LPM, and the sample is illuminated with a halogen lamp and measures scattered light at 450, 550 and 700 nm using three photomultiplier tubes. The nephelometer contains one humidity and two temperature sensors. The humidity sensor and one temperature sensor are located near the sample outlet and the other temperature sensor is located at the sample inlet.

The scattering coefficient shows a minimum dependence on RH at <50% and sharp increase at >80% RH (Anderson and Ogren, 1998; Xu et al., 2002). Calibration of the nephelometer has been carried out twice per year by using CO_2 as high span gas and filtered dry air as low span gas. These data are recorded with a temporal resolution of 1 min, and the zero signals are measured for every 5 min in a hour. The total scattering and backscattering data are corrected on a systematic basis considering the angular truncation errors (Anderson and Ogren, 1998).

The meteorological parameters like Air Temperature (AT), Relative Humidity (RH), Rain Fall (RF), and Wind Speed (WS) have been measured by using Mini Boundary Layer Mast (MBLM) installed near the measurement location. The daily surface wind flow patterns at Anantapur site have been obtained from NCEP/NCAR reanalysis data (http://www.cdc.noaa.gov).

4. Methodology

The scattering and backscattering coefficients at three different wavelengths are measured by using TSI Model 3563 Integrating Nephelometer. The scattering Ångstrom exponent (Å) represents the wavelength dependence of scattering coefficient and can be related to a mean size of the particle. It was calculated using the 450 and 700 nm channels as follows (Pereira et al., 2011).

$$\text{Å} = -\frac{\log\left(\sigma_{sp}^{\lambda_1}\right) - \log\left(\sigma_{sp}^{\lambda_2}\right)}{\log(\lambda_1) - \log(\lambda_2)} \tag{1}$$

In the above equation $\sigma_{sp}^{\lambda_1}$ and $\sigma_{sp}^{\lambda_2}$ are the scattering coefficients obtained at the wavelengths of λ_1 (700 nm) and λ_2 (450 nm) respectively.

The backscattering ratio is the ratio of the backscattering coefficient over the scattering coefficient at a given wavelengths (450, 550 and 700 nm).