Association of aerosol optical depth with near surface aerosol properties in urban environment

K Madhavi Latha & K V S Badarinath
National Remote Sensing Agency, Balanagar, Hyderabad 500 037
[Email: badrinath_kvs@nrsa.gov.in]

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Changes of near surface aerosol properties and their association with aerosol optical depth studied over tropical urban environment in Hyderabad during January-May, 2003 corresponding to winter and summer seasons have been presented. Aerosol Optical Depth (AOD) has been studied using MICROTOPS-II sunphotometer and aerosol size distribution has been studied using Quartz Crystal Microbalance Particle analyzer. Results from the study suggest that the temporal variation of near surface sub-micron aerosol mass concentration and columnar aerosol optical depth at 500 nm are well correlated. Aerosol size index as well as Angstrom wavelength exponent has been found to be high during February, indicating relative dominance accumulation mode particles. During summer season Angstrom exponent values have been found to be low indicating relative dominance of coarse mode particles.

Keywords: Aerosol optical depth, Urban environment, Aerosol mass concentration, Aerosol size distribution

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1 Introduction

Aerosol optical properties have a temporal variability correlated with different atmospheric scale processes and are also dependent on local and regional events from natural and anthropogenic nature such as biomass burning, urban and non-urban processes, volcanic eruptions and air borne soil particles. In all these cases, near surface or boundary layer aerosols are important as they influence visibility, impair human health and produce radiative effects. Their properties are closely related to the source processes as their mass and number concentrations are large and the size distribution spans a large range of temporal and spatial variabilities. Aerosol size distribution influences the dynamics of aerosol population, their production and removal process, the size transformation, lifetime, optical properties and radiative effects. Characterization of the size distribution of atmospheric aerosols is valuable as aerosols modify the microstructure of clouds by acting as condensation nuclei. Studies on the temporal and spatial changes of aerosol characteristics give insight into the origin of particles. Size distribution of atmospheric aerosols strongly depends on the sources and sinks as well as on the meteorological processes that prevail during their lifetime, on the type and history of the air mass, as well as on the boundary layer circulations. Atmospheric effects of aerosols strongly depend upon their size, number concentration, chemical and optical properties. In this paper, we present the characteristics of near surface aerosols and their role in producing changes in the columnar optical depths.

2 Experimental details

Near real-time measurements of total, as well as size segregated mass concentration of near surface aerosols have been carried out using a ten channel Quartz Crystal Microbalance (QCM) Impactor for particle diameters in the range 0.05-25 μm at the typical urban environment Hyderabad (17° to 17°50’N latitude and 78°10’ to 78°50’E) during the period of January-May, 2003 (Fig. 1). Measurements have been carried out at Balanagar site corresponding to 17°28’ N and 78°26’ E in Hyderabad city. During this period, a total of ~ 400 independent observations of mass concentration were used to study the number-size distribution over the study area. The measurements have been carried out during 8:00-18:00 hrs. The mass concentration radius range from 0.4 to 0.05 μm has been considered as submicron mass concentration. MICROTOPS-II sunphotometer has been used to measure aerosol optical depth at different wavelengths, viz., 380, 440, 500, 675, 870 and 1020 nm.
3 Methodology

The spectral variation of $\tau_p$ is closely related to the aerosol column size distribution $[n_c(r)]$ through the relation

$$\tau_{pk} = \int_1^2 \pi r^2 Q_{ext}(\lambda, r, m) n_c(r) \, dr$$

where $r$ is the radius of the particle, $Q_{ext}$ the extinction efficiency, $n_c(r)$ the columnar size distribution and $m$ the complex refractive index of aerosols. A simple way of relating $\tau_{pk}$ to $n_c(r)$ is through the Angstrom relation, which states

$$\tau_{pk} = \beta \lambda^{-\alpha}$$

where $\lambda$ is wavelength in $\mu$m, $\tau_{pk}$ is the measured AOD, $\alpha$ is the wavelength exponent and $\beta$ the Angstrom turbidity coefficient. The value of $\alpha$ is an indicator of aerosol size distribution and $\beta$ a measure of aerosol columnar loading. The number density size distributions of sub-micron aerosols have been deduced for each QCM measurements and have been averaged over each month. The aerosol size index $v$ has been obtained from the distribution by fitting a Junge Power law of the form

$$dn_C = \frac{C}{r^v}$$

where $C$ is a constant depending on the total number of particles.

For a power law size form for $n_c(r)$, the Angstrom wavelength exponent $\alpha$ and aerosol size index $v$ are related as $v = \alpha + 2$.

4 Results and discussion

Spectral variation of monthly mean aerosol optical depth (AOD) at different bands viz., 380, 440, 500, 675, 870 and 1020 nm during January-May 2003 has been shown in Fig. 2. The spectral variation of AOD shows three peaks at 380, 500, and 875 nm, suggesting multi-modal aerosol size distribution over the study area. Junge's inverse power law distribution suggests that there should be a gradual decrease in the aerosol optical depth with increasing wavelength. The observed spectral variation of aerosol optical depth does not show such a feature, indicating that the aerosol size distribution does not follow the Junge's power law distribution. High AOD has been observed at 380 nm, suggesting high accumulation mode particle loading over the study area. Similar spectral variation has been observed in other studies over Indian region.

Figure 3 shows the variation of AOD at 500 nm and submicron mass concentrations for different months. AOD is observed to be minimum in January and February 2003, which can be due to weak generation mechanisms and gas-to-particle conversion processes and also due to the less possibility of hygroscopic growth of aerosols due to low water vapour content. Maximum AOD is observed during April and has been attributed to increased aerosol input due to
mass concentration influences the optical depth. However during January, due to low temperatures and related inversion processes over the study area, near surface aerosol concentration is high and the correlation becomes poor. Similar observations have been reported at other places over India. The coefficient is not very high (even though it is quite significant) because of other contributors to AOD such as size distribution, altitude distribution and composition etc.

The variation of $\alpha$ and $\nu$ are shown in Fig. 5. Even though there is no one-to-one correspondence, there is good association between $\alpha$ and $\nu$. High values of $\alpha$ and $\nu$ are observed in February indicating the relative dominance of small particles. The values of $\alpha$ and $\nu$ are gradually decreased from February to May. The low value of $\alpha$ and $\nu$ during May, indicates relative dominance of larger particles. The difference in $\nu$ and $\alpha$ ($\nu-\alpha$) remain nearly 2. Similar observations have been reported at other places over India. The comparison of values of $\alpha$ with other studies suggests that the Angstrom exponent for Hyderabad is comparable to Kansas (USA), Kathmandu (Nepal), Jakarta (Indonesia) and Pune (India).

### 5 Conclusions

(i) Aerosol optical depth values over the study area gradually increased from January to April and then decreased in May. Temporal variation of near surface sub-micron aerosol mass concentration and columnar aerosol optical depth at 500 nm are well associated.

(ii) Aerosol size index derived from QCM as well as Angstrom wavelength exponent have been found to be high during February, indicating relative dominance of small sized particles and low during May indicating relative dominance of large particles.

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### References


