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# URBAN AEROSOL AND PRE-CURSOR GAS CHARACTERIZATION: SYNERGY BETWEEN TWO DECADES OF AEROSOL LIDAR, RADIOMETER AND SATELLITE DATA OVER PUNE, INDIA

**R.L. Bhawar, P.C.S. Devara, S.K. Saha, P. Ernest Raj, Y. Jaya Rao, G. Pandithurai, K.K. Dani and S.M. Sonbawne**

*Indian Institute of Tropical Meteorology, Pune 411 008, India*
*Tel: +91-020-25893600; Fax: +91-020-25893825; e-mail: devara@tropmet.res.in*

## Introduction

Remotely measured atmospheric aerosol optical parameters are important for various applications including computations of radiative forcing and satellite remote sensing (King et al., 1999). The major advantage of these kind of remote sensing measurements over direct *in-situ* aerosol sampling or laboratory analysis is their large-scale (column-integrated quantities) and non-intrusive nature. Satellite-based remote sensing methods, in conjunction with ground-based methods, have produced promising results (Kaufman et al., 2000; Tanre et al., 2001).

In this paper the results of investigations into long-term trends and changes in atmospheric aerosol column content (ACC) in the boundary layer, columnar aerosol optical depth (AOD) determined from ground-based aerosol lidar and the sunphotometer version of Microtops-II, respectively, over a tropical urban station, Pune (18.5$^o$N, 73.5$^o$E, 559 m AMSL), India, are discussed. The AODs at near-common wavelengths between the Microtops and those observed concurrently by MODIS, MISR and TOMS satellite payloads are compared. The lidar observational program involves minimum 2 and maximum 8 vertical profiles of aerosol number density in the lower troposphere in each month, and solar irradiance observations at six wavelengths ranging from UV to NIR region from sunphotometer on all clear-sky days. More than 1000 weekly-mean vertical profiles of lidar observations during October 1986-December 2006, and sun-photometric measurements on about 750 cloud-free days from September 1998 through October 2006 have been used in this study.

## Methodology

The lidar system used in the present study is basically of bistatic type having a tunable Argon-ion laser as transmitter and a 25-cm Newtonian telescope-based detection system as receiver. Thus the scattered signal strength, after removing the background noise and contribution due to air molecules, obtained by sampling vertically transmitted laser beam into the atmosphere with the telescope at different scattering angles yields vertical profiles of aerosol number density using inversion algorithms (Devara et al., 1995). The aerosol columnar content was also estimated by integrating each profile of aerosol concentration throughout its height range. The multi-channel solar radiometers (sunphotometer and ozonometer versions of MICROTOPS-II) used in the present study measure basically the relative flux of directly transmitted sunlight received at the Earth's surface at different wavelengths as a function of solar zenith angle. The AODs were deduced by following the Langley method and by accounting for contributions due to air and gas molecules (Devara et al., 1996; 2001). The radiometers have been operated at the site almost on all clear-sky days including the days of lidar observations. The Total Ozone

Mapping Spectrometer (TOMS) derived aerosol optical depth (AOD) data at 550 nm wavelength from Moderate resolution Imaging Spectrometer (MODIS) and Multi-angle Imaging Spectroradiometer (MISR) have also been utilized in this study for (i) comparison between AODs retrieved from different complementary techniques, (ii) investigating long-term trends and changes in aerosol optical and microphysical parameters, and (iii) determining the correspondence between aerosol loading, total column ozone and precipitable water content at the experimental station.

**Discussion of Results**

Figure 1 depicts variations in the monthly mean ACC determined from lidar observations during October 1986 through December 2006. The regression fit to the data yields

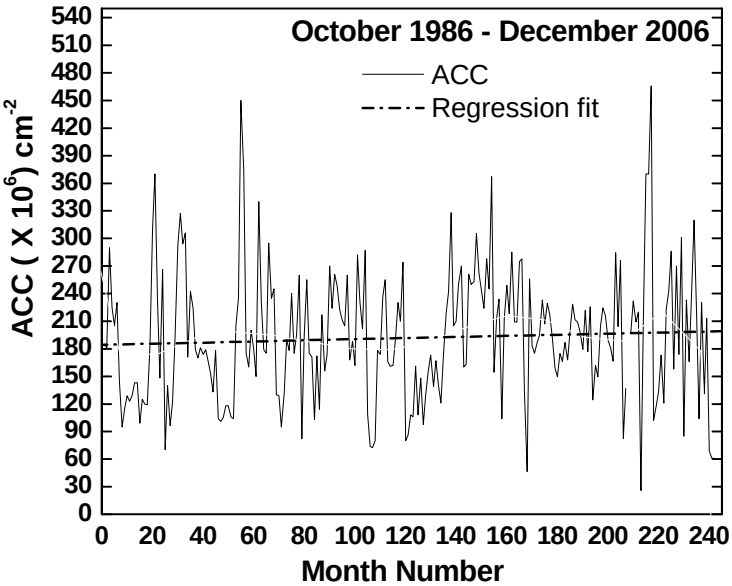


**Figure 1**: Monthly mean variation in lidar-observed aerosol loading at Pune. Thick dashed line represents long-term trend during two decades

long-term climatological trend which indicates an increase of about 10 per cent in aerosol loading at Pune. This suggests an influence of the monthly, inter-annual and intra-seasonal variability of aerosol particle concentration in modifying the long-term trend in aerosol loading. This enhancement in aerosol loading is ascribed to growth in urbanization, particularly the land-use pattern changes involving construction of buildings and associated urban heat island-induced radiative effects resulting from differences in day and night temperature in Pune city and adjoining sub-urban areas.

The AOD observations carried out on clear-sky days using a collocated Microtops II at six wavelengths (380, 440, 500, 675, 870 and 1020 nm) over Pune for the period from May 1998 to February 2006 have been examined in Figure 2. This plot indicates 24% and 10% increase in

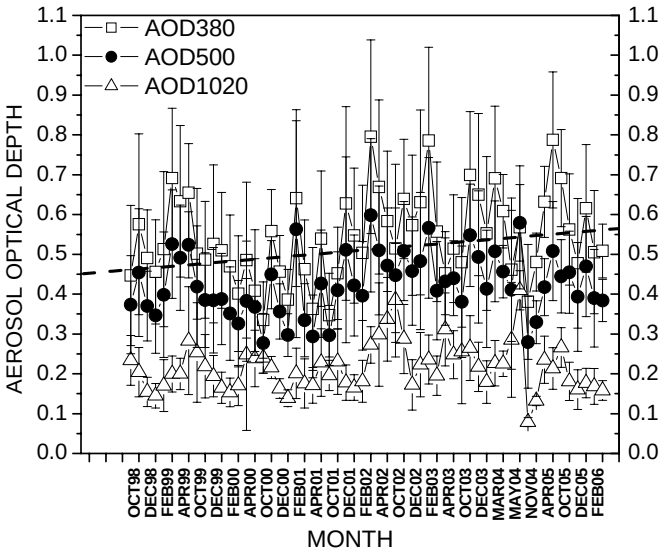


**Figure 2**: Monthly mean variation of AOD at wavelengths representative of fine, sub-micron and coarse-mode aerosol particles during 1998-2006. Vertical bars represent error in measurement. Dashed line indicates regression fit line for AOD at 500 nm.

AOD, respectively, at fine and sub-micron particle loading while it showed about 33% decrease in AOD at coarse-mode particles. This clearly suggests that significant increase in anthropogenic addition of fine aerosol particles mainly due to land-use pattern changes associated with constructional activities as compared to the naturally driven coarse-mode particles.

Figure 3 compares the AOD measured simultaneously from the ground-based and space-borne radiometers over the experimental station. The results reveal (a) an increasing trend in

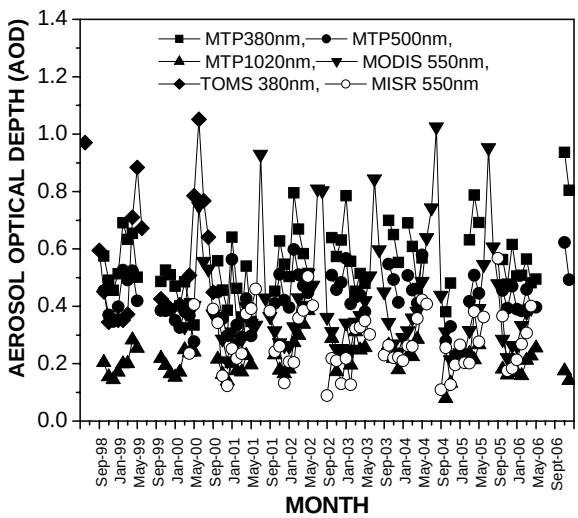


**Figure 3**: Comparison between aerosol loading measured by ground-based solar radiometer over Pune and concurrent satellite estimates.

aerosol loading/extinction which could be mainly due to growth in urbanization, industrialization and land-use pattern changes, (b) the largest temporal inhomogeneity of

integral atmospheric transparency is caused by both fine and coarse mode aerosol particles, and in most of the time the coarse aerosol is principal contributor to the extinction of radiation, and (c) MODIS and MISR underestimate AOD and overestimates water vapor as compared to Microtops-sunphotometer, while column ozone shows good agreement between TOMS and Microtops-ozonometer.

**Conclusions**

The data of aerosol loading for two decades, determined from lidar and solar radiometers over Pune reveal an increasing trend due to growth in urbanization. The columnar AOD, ozone and water vapor retrieved from Microtops-II are found to be in fair agreement with such estimates made from satellite observations. As both lidar and solar radiometric observations are continuing at IITM, more inferences delineating long-term variability in aerosol loading and its impact on weather and climate are planned in future work.

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