H-O-4

Long-term variations of Aerosol Optical Thickness, Angstrom Exponent and Aerosol Radiative Forcing estimates over Delhi

Rajesh Kumar, Sachchidanand Singh, Tarannum Bano, Shambhu Nath & R.S. Tanwar

Radio & Atmospheric Sciences Division, National Physical Laboratory
New Delhi –110012

Abstract

The Aerosol Optical Thickness (AOT) from December 2001 to January 2007 obtained using the MICROTOPS sunphotometer during daytime clear sky conditions have been studied over Delhi. The Angstrom exponent α was estimated for different wavelength rages as $\alpha_{340-500}$, $\alpha_{340-870}$ and $\alpha_{870-1020}$, where the suffix denotes the wavelengths in nm. Based on the values of AOT and α, the OPAC (Optical Properties of Aerosol and Clouds) model was used to estimate the aerosol optical properties (single scattering albedo, phase function) over Delhi during the observation period. The same was then used to obtain the Aerosol Radiative Forcing (ARF).

Introduction

The atmospheric aerosols are found to significantly affect the radiation budget of the earth directly by scattering and absorption and indirectly by interacting with clouds and through chemical reactions. The effect called the aerosol radiation forcing (measured in W/m^2) at the top of the atmosphere (TOA) and at the surface is defined as the difference in the net fluxes (down minus up) with and without aerosol at the TOA and at the surface levels, respectively. The estimation of ARF requires a prior knowledge of various optical parameters of atmospheric aerosols like AOT, SSA (single scattering albedo), asymmetry parameter; profiles of atmospheric constituents, temperature, humidity and pressure; solar geometry and surface albedo values. In the present study the AOT data was obtained from the MICROTOPS and optical properties of the aerosols were estimated using OPAC model (Hess et al., 1998). The inputs were then used to compute the net flux in the wavelength range 0.3–3.0 mm with and without aerosols at the top of the atmosphere (TOA) and at the surface separately using the Santa Barbara DISORT Atmospheric Radiative Transfer (SB-DART) model (Ricchiazzi et al., 1998).

Observations

The AOT observations are regularly taken on working days during the daytime clear-sky conditions using the MICROTOPS. MICROTOPS are hand held microprocessor-based sunphotometers from Solar Light Co., USA, which, if properly calibrated and pointed accurately to sun provide fairly accurate measurements of AOTs at 340, 500, 675, 870 and 1020 nm. The values are comparable in accuracy to the CIMEL sun photometers during clear sky conditions. The measurements at NPL are taken regularly during clear sky days since December 2001. Two sets of instruments are maintained so that the calibrations are done once a year by sending the instruments to Mauna Loa observatory, USA.

Results and Discussions

Figure-1 shows average monthly AOT at 500nm from Dec 2001 to Jan 2007. A clear rise in AOD during pre-monsoon months of April-June every year may be noticed. The monthly average AOT_{500} during these months goes as high as 1.5 due to the desert dusts from the western region. It is however important to note that the Average monthly AOT_{500} over Delhi is always more than 0.5. The Angstrom exponent α, that characterize the aerosol size distribution were obtained for three different wavelength ranges, 340-500nm, 340-870nm and 870-1020nm. Figure-2 shows the average monthly values for the three Angstrom exponents $\alpha_{340\text{-}500}$, $\alpha_{340\text{-}870}$ and $\alpha_{870\text{-}1020}$. The $\alpha_{340\text{-}500}$ and $\alpha_{340\text{-}870}$ show more or less similar value but the $\alpha_{870\text{-}1020}$ values are quite different.

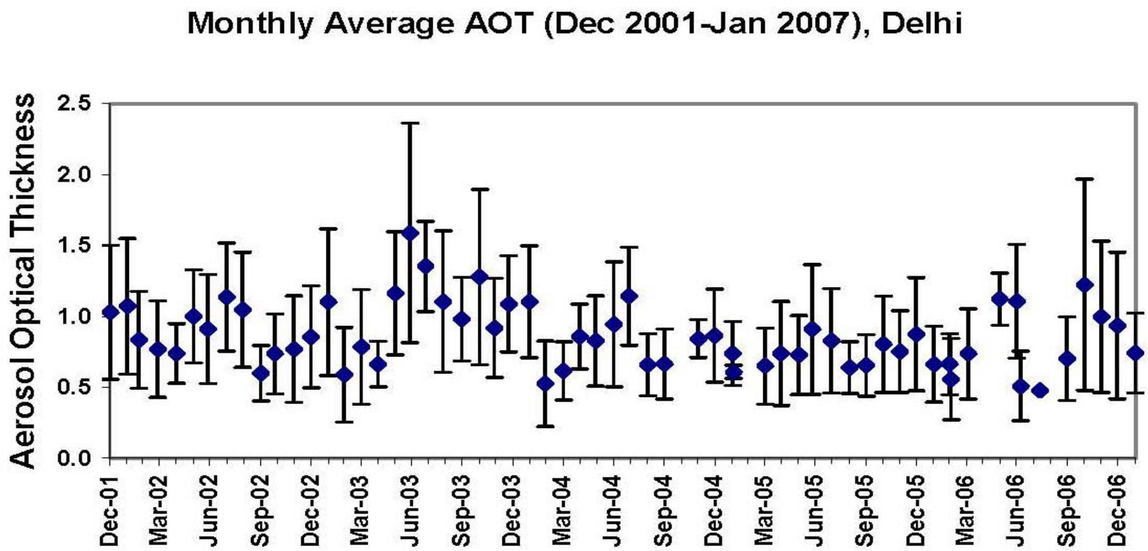

Figure 1. Monthly AOT variation over Delhi during Dec 2001 to Jan 2007

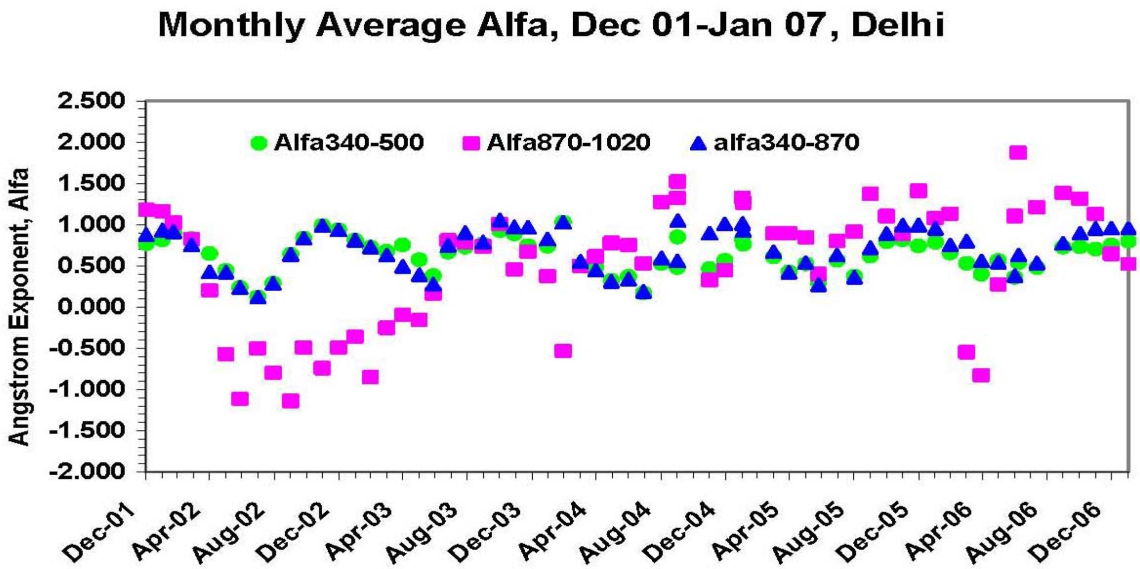

Figure 2. Monthly variation of α over Delhi during Dec 2001 to Jan 2007

On the early basis, three kinds of seasonal variation of aerosol are noticed over Delhi. During pre-monsoon period high AOT values are associated with near zero α values (indicating dominance of desert aerosols), in the post monsoon to winter period moderate AOT values are associated with the moderate to high α values (indicating dominant anthropogenic aerosols), and during autumn season moderate to low AOT are associated with the moderate to high α values (due to mixed aerosols). The Angstrom exponent shows a typical wave like structure with minimum during summer and maximum during winter every year indicating dominance of coarse particles during summer and fine particles during winter.

The aerosol model developed by Hess et al (1998) was used to calculate the SSA and the asymmetry factor for the aerosol composition over Delhi during the period of observation. For most of the months the ‘urban’ aerosol type was sufficient to give the required aerosol component, except that the number concentration for the soluble, insoluble and the soot particles were changed to derive the AOTs. During pre-monsoon period however, no single aerosol type given by Hess et al represented the Delhi aerosols. A combination of two aerosol types, ‘urban’ and ‘desert’ best represented the aerosol characteristics during this period as described by Singh et al. (2005). The concentrations of various components are adjusted so that the AOT estimated from the OPAC model matched with the Observations.

The SSA and the asymmetry factor thus obtained from the OPAC model was then used in the SBDART radiative transfer model to estimate the ARF at the surface and TOA. The model was run at 1-h interval for a 24-h period and average forcing was estimated during each month for cloud free clear-sky conditions. Based upon the measured parameters and the prevailing weather conditions, we have used the mid-latitude summer atmospheric profile along with an average integrated water vapor column for each month and a fixed value of surface albedo 0.25. The model is run with eight streams to obtain the TOA and the surface aerosol forcing.

References:

1. Hess, M., P. Koepke, and I. Schult (1998), Optical properties of aerosols and clouds: The software package OPAC, Bull. Am. Meteorol. Soc., 79, 831– 844.
2. Ricchiazzi, P., S. Yang, C. Gautier, and D. Sowle (1998), SBDART: A research and teaching software tool for plane-parallel radiative transfer in the Earth’s atmosphere, Bull. Am. Meteorol. Soc., 79, 2101– 2114.
3. Singh, S., Nath, S., Kohli, R., Singh, R. (2005), Aerosols over Delhi during pre-monsoon months: Characteristics and effects on surface radiation forcing. Geophys. Res. Letters 32, L13808. doi:10.1029/2005GL023062.