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THREE YEAR SUN/SKY RADIOMETER MEASUREMENTS OF AEROSOL OPTICAL PROPERTIES OVER AN URBAN SITE: EFFECTS ON LOCAL DIRECT RADIATIVE FORCING AND HEATING RATES

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1. Introduction

The radiative forcing due to aerosols is poorly characterized in climate models because of the lack of comprehensive database on aerosol optical properties. To fill this gap, numerous field experiments have been undertaken in recent years. Even though field experiments provide very good snapshot information of aerosol radiative properties, the temporal coverage is not so adequate, since the experiments are limited to a short duration of time, spanning from few days to over a month. Recent studies have pointed out that the radiative forcing due to aerosols is comparable to that of greenhouse gases, but opposite in sign [IPCC, 2001]. The radiative heating/cooling by aerosols must also be known to predict adequately the overall impact of aerosols on weather and climate because heating/cooling by atmospheric aerosols alters atmospheric dynamics and thermodynamics. Direct observations of radiative forcing and radiative heating/cooling rates are scarce and difficult. Models remain a powerful tool to study the radiative forcing and heating rates due to aerosols. However, models need appropriate input parameters such as aerosol optical depth, single scattering albedo, and asymmetry parameter, etc. In this study, we present aerosol radiative forcing (ARF) and heating rates estimated over Pune, using sun/sky radiometer derived aerosol radiative parameters collected for 3 years period 2001, 2002 and 2004.

2. Data and Methodology

A Prede sun/sky radiometer [POM-01L, Prede Inc. Japan] is operated at the Indian Institute of Tropical Meteorology (IITM), Pune to make sun/sky observations that can be used to retrieve radiative characteristics of aerosols. The instrument provides highly accurate angular and spectral scans with scan accuracy of ±1° with a maximum scan rate of 30 degrees/sec. Calibration methodology and data reduction procedures for this instrument are presented in Nakajima et al. (1996) and Boi et al. (1999). The sun/sky radiance data collected from December 2000 to April 2004 are used in the present study. Column aerosol radiative parameters such as aerosol optical depth (AOD), single scattering albedo (SSA) and asymmetry parameter (ASY) were derived from sun/sky radiance data at 5 wavelengths (400, 500, 675, 870 and 1020 nm) covering the visible to near infra-red spectral regions, using the radiative transfer model skyrad.pack version 4.2 (Nakajima et al. 1996). Monthly mean AOD, SSA and ASY at 400, 500, 675, 870 and 1020 nm wavelengths derived from sun/sky radiometer, monthly mean precipitable water content and total column ozone derived from MODIS and TOMS were used as inputs in the radiative transfer model Santa Barbara Discrete-ordinate Atmospheric Radiative Transfer (SBDART) [Ricchiazzi et al. 1998] to simulate shortwave (SW, 0.3-3.0 µm) fluxes at the surface for aerosol laden and aerosol-free atmospheres. MODIS black and white sky albedos at different spectral bands for January and April is used for computing actual surface albedos for this site, representative to winter and pre-monsoon seasons (Moody et al. 2004).

3. Results and Conclusion

From the daily mean, monthly mean values of AOD, SSA and ASY were calculated for the period considered in the study. Monthly mean AOD at 500 nm varies in the range from 0.28 to 0.97, SSA range from 0.79 to 0.87 and ASY range from 0.65 to 0.72. Higher AOD values were observed during year 2002 as compared to other years considered in the study. In general, higher AODs and lower SSA values were observed during pre-monsoon indicating the dominance of absorbing type of aerosols in this season. But in year 2004, SSA values are observed to be lower in winter as compared to pre-monsoon. This seasonal asymmetry in aerosol optical properties can be due to the influence of local meteorological conditions. Figure 1 shows the monthly mean direct ARF at the surface, top of the atmosphere (TOA) and atmosphere in the SW spectral region for the dry period of 2001-2004. Direct ARF values ranging from -23 to -71 Wm^{-2} at the surface and -0.8 to -9.6 Wm^{-2} at the TOA for AOD range of 0.28 to 0.97. These surface forcing values have strong negative correlation (-0.95) with AOD at 500 nm. The radiative forcing efficiency (F_{eff}), which is the aerosol forcing per unit AOD at 500 nm has also been computed and shown in Figure 1 for SFC, TOA, and ATM. Mean F_{eff} values at the surface, TOA and atmosphere is found to be -80, -11 and 69 Wm^{-2}. The sign of the aerosol forcing at the TOA depends on surface albedo, SSA and asymmetry parameter. Knowledge on aerosol radiative forcing during different seasons would be useful in studying the impact of aerosols on ensuing monsoon rainfall. Atmospheric heating rate plays an important role through modifying atmospheric dynamics.

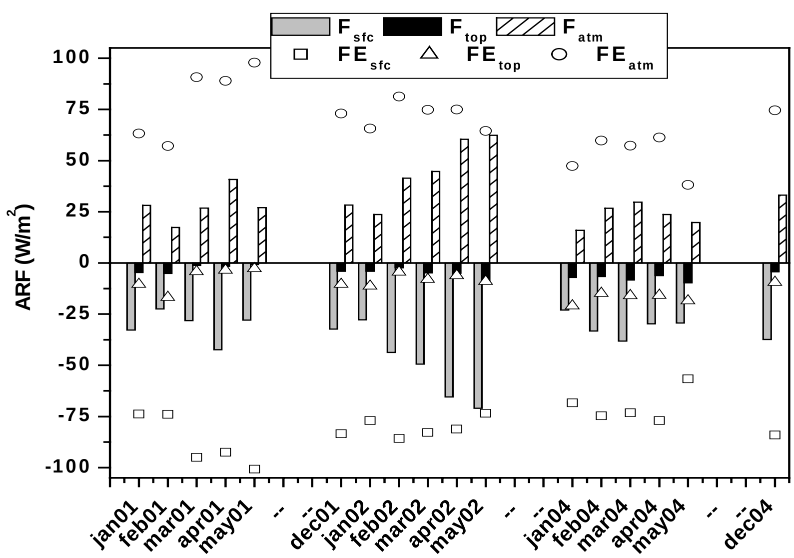

Figure 1. Month-to-month variation in aerosol radiative forcing at the surface, TOA and in the atmosphere over Pune during January 2001 – December 2004 (Forcing efficiencies also indicated in the figure).

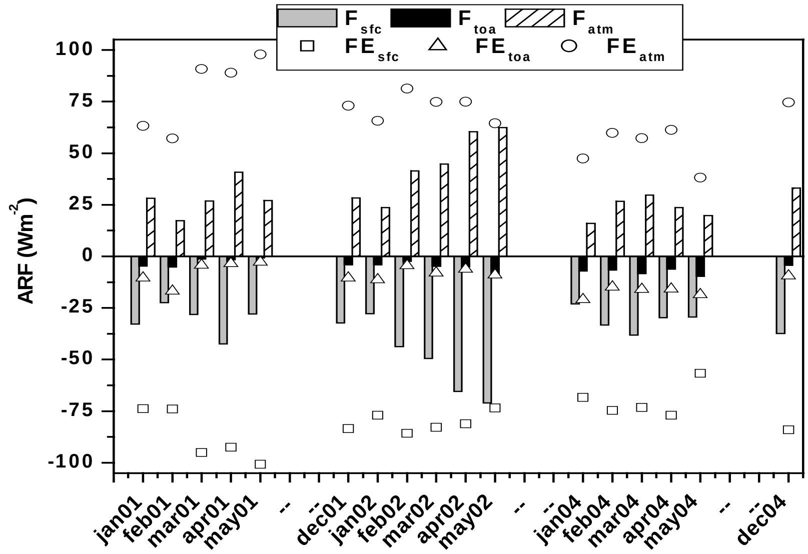

Figure 2 shows the Month-to-month variation in aerosol heating rate in the lower atmosphere (up to 5 km) over Pune during January 2001 – December 2004. The mean heating rates are 0.85 and 0.5 K/day, respectively during pre-monsoon and winter. Higher heating rate during pre-monsoon is due to relatively large aerosol loading and the abundance of absorbing aerosols.

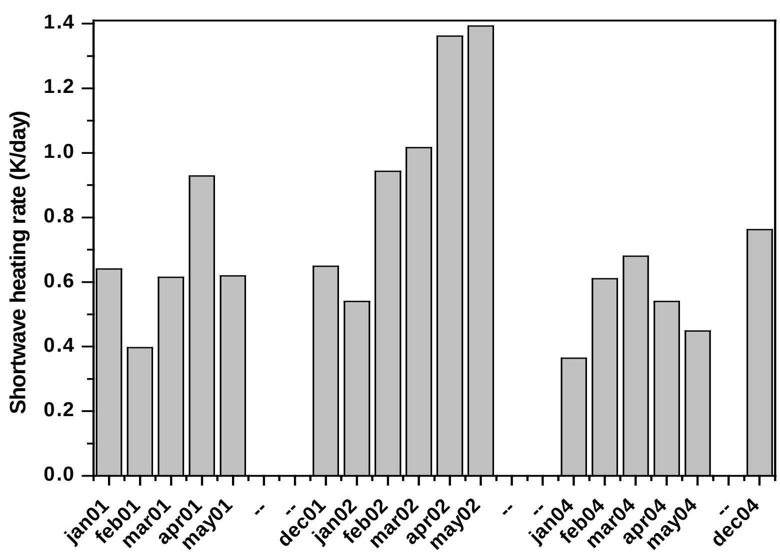

Figure 2. Month-to-month variation in mean aerosol heating rate in the lower atmosphere (upto 5 km) over Pune during January 2001 – December 2004

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