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Short Communication

Effect of diurnal variation of aerosols on surface reaching solar radiation

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ABSTRACT

In this report, we attempt to quantify direct aerosol radiative forcing by considering the diurnal variation of aerosols over central Himalayan region. The measured day time aerosol optical depth (AOD) values are higher by a small magnitude $\leq 15\%$ during forenoon and reached as high as 90% by late afternoon when compare to night time AOD. The above observation gives clue about transport of regional polluted aerosols to the observational site. Our results show, 10 (16) % increment in atmospheric radiative forcing due to diurnal variation of aerosols instead of average aerosols during winter (post-monsoon) season.

1. Introduction

Atmospheric aerosols affect climate directly by scattering/absorbing the incoming short-wave and outgoing-long wave radiation, and they also affect the climate indirectly by modifying the cloud micro-physical properties, cloud life time, precipitation and etc. In addition, aerosols cause semi-direct effect by substantially heating the atmosphere relative to the surface. This reduces upward movement of moisture air transport and leads reduction of cloud coverage (Wang, 2013). Other significant effects of aerosols include reduction of albedo on snow surface due to black carbon aerosol deposition (Hadley and Kirchstetter, 2012), on health (Varotsos et al., 2012), on the corrosion and soiling effects on materials (Tzanis et al., 2011), on the solar ultraviolet radiation reaching the ground (Chubarova, 2004; Tzanis et al., 2009) and etc.

The effect of aerosols on climate is normally quantified in terms of radiative forcing and it depends on the properties, mixing state, vertical distribution of aerosols and reflecting underlying surface (Gadhavi and Jayaraman, 2010; Satheesh et al., 2010; Marcq et al., 2010; Kishore et al., 2013). However, the estimation of aerosol radiative forcing are not constrained well in global and regional scales due to inadequate data sets on the optical properties of aerosols (due different types of aerosol species present in the atmosphere and their mixing states) (Auromeet et al., 2008; McMeeking et al., 2011), vertical distribution of aerosols and underlying reflecting surface especially in the cloudy atmosphere (Marcq et al., 2010; Kishore et al., 2013).

Previous reports showed that the column integrated aerosol mass concentrations are almost same throughout day over low altitude stations viz. Bangalore implying negligible diurnal variation in AOD and other optical properties (Satheesh et al., 2010). However, the column integrated aerosol mass concentration increases as day progress over high altitude stations viz. Manora Peak (Dumka et al., 2006) in India, Pyramid site in Nepal (Marcq et al., 2010). This leads huge diurnal variability in AOD (high loading during afternoon hours) and other optical properties attributed to boundary layer dynamics and topography of observational site. Due to this diurnal variability, the average optical properties of aerosols may be under/over estimation with instantaneous properties over high altitude stations. Hence, it is important to consider the instantaneous aerosol optical properties for accurate estimation of radiative forcing. Earlier studies from Manora Peak emphasized the importance of characterization of aerosols and its influence on the atmospheric forcing (Dumka et al., 2008; Srivastava et al., 2012a, 2012b). However, average optical properties of aerosols have been used in the estimation of aerosol radiative forcing and this has been a common practice in most of the studies in the past (Gadhavi and Jayaraman, 2010; Panicker et al., 2010; Srivastava et al., 2012a).

In this context, we attempt to understand the effect of diurnal variation of aerosols on radiative forcing over central Himalayan region. In this direction, we utilized black carbon mass concentration, AODs at different wavelengths and vertical profile of

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aerosols during winter and post-monsoon seasons in 2008 over Manora peak as a part of Aerosol Radiative Forcing over India (ARFI) and Atmospheric Boundary Layer Network and Characterization (ABLN&C) projects under Indian Space Research Organisation-Geosphere Biosphere Program (ISRO-GBP). The hourly values of measured parameters are used to estimate diurnal variation of aerosol optical properties and further these properties have been considered to calculate aerosol direct radiative forcing in clear sky conditions. The obtained results are compared with earlier methodology values and the observed discrepancies were discussed in the light of current understanding of aerosol optical properties in radiative forcing estimations.

2. Site description and instrumentation

As shown in Fig 1a and b, Manora Peak (29.4°N, 79.5°E), Nainital is a high altitude location in the central Himalayan region with an elevation of 1958 m asl. The site is representative of background aerosols as it is in the free troposphere and far off from any major anthropogenic activities. Detailed site description and meteorological conditions were explained in Sagar et al. (2004). Data used in the present study are obtained during 2008 for winter (November–December) and post-monsoon (September–October) seasons.

2.1. Aethalomerer

Black carbon (BC) mass concentration measurements were performed by Aethalometer (AE-42 of Magee Scientific, USA) based on the principle of attenuation of light beam due to particles deposited on the quartz filter paper in the wavelength range of 0.37–0.95 μm (namely 0.37, 0.47, 0.52, 0.59, 0.66, 0.88 and 0.95 μm) for every 15 min. In the present study, we have used BC mass concentration measured at 0.88 μm wavelength as other aerosols are having negligible absorption at this wavelength (Bergstrom, 1995). The overall uncertainty in the BC mass concentrations reported in this study is less than 10%. More details on the instrumentation and the principle of measurements were found in Hansen et al. (1984).

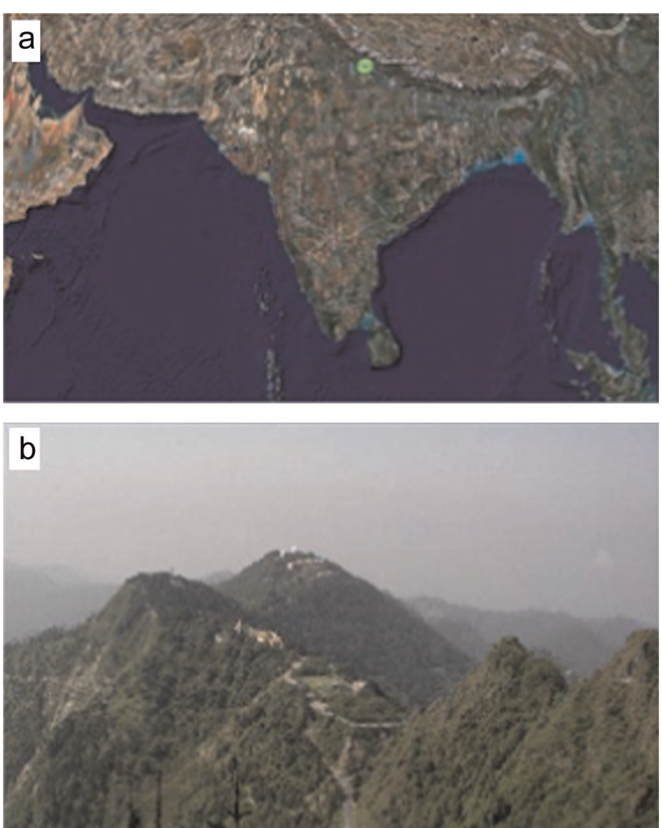

Fig. 1. (a,b) Location and topography of the Manora Peak in the foot hills of central Himalayan region.

2.2. Microtops (sun photometer)

The direct fluxes were measured at five wavelengths namely 0.38, 0.44, 0.50, 0.675 and 0.87 μm with a full width-of-half minimum of 0.006–0.01 μm, using Sun photometer (Microtops) II (Solar Light Company, Glenside, PA, USA) to get AODs at each wavelength. A global positioning system (GPS) receiver connected to the photometer provides the information about time, location, altitude and pressure. The observations were taken daily during clear day time sky conditions between 09.00–17.00 h local time with half an hour interval for each day. The typical error in the AOD measurements using Microtops II sun photometer is ± 0.03. More details regarding the Sun photometer, methodology of data acquisition and precautions during measurements and its calibrations are described in previous papers (Morys et al., 2001; Porter et al., 2001; Ichoku et al., 2002).

2.3. Lidar

A portable Boundary Layer Lidar (BLL) is used to study the vertical profile of aerosols. The Lidar system employs a diode pumped Nd: YAG (Neodymium-doped Yttrium Aluminum Garnet) laser that operates at 0.532 μm with 10 μJ energy and 2.5 kHz pulse repetition rate. Lidar system collects backscattered light from the atmospheric constituents such as molecules and aerosols by 150 mm diameter Cassegrain telescope. The complete overlap between the laser beam and the telescope field of view occurs at 150 m, which represents the lower limit of vertical profiles. The detection section is comprised of a high gain photo multiplier tube (PMT) for photon detection, a fast discriminator (300 MHz) and a PC based multi channel scalar (MCS) add-on card. The backscattered photons from atmospheric constituents get stored with a bin width of 200 ns which corresponds to an altitude resolution of 30 m. The data was obtained at least 4–6 h after the sunset except for the cases of extreme weather conditions. The detailed system description is given elsewhere by Bhavani Kumar (2006).

3. Results

3.1. Diurnal variation of black carbon mass concentration and aerosol optical depth

The aerosol concentration at Manora Peak is representative of background aerosols as it is considered to be high altitude site (1958 m amsl) and mostly it is in the free troposphere region (Sagar et al., 2004). The measured averaged black carbon (BC) mass concentrations were 1.9 ± 0.41 μg m^{-3} and 0.64 ± 0.24 μg m^{-3} during winter and post-monsoon seasons respectively. Fig. 2 shows, the hourly averaged diurnal variations in black carbon (BC) mass concentrations during winter and post-monsoon seasons. The measured black carbon mass concentration showed large diurnal variations with low values ~0.4 μg m^{-3} and ~1.6 μg m^{-3} during late night and early morning hours (00–09 h) and high values during afternoon hours with peak values 2.77 μg m^{-3} and 1.03 μg m^{-3} during winter and post-monsoon seasons respectively. The diurnal variation of surface black carbon