Radiative effects of aerosols over Indo-Gangetic plain: environmental (urban vs. rural) and seasonal variations

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Abstract Aerosol radiative effects over two environmentally distinct locations, Kanpur (urban site) and Gandhi College (rural location) in the Indo-Gangetic plain (IGP), a regional aerosol hot spot, utilizing the measured optical and physical characteristics of aerosols, an aerosol optical properties model and a radiative transfer model, are examined. Shortwave aerosol radiative forcing (ARF) at the top of the atmosphere (TOA) is $<-12$ W m$^{-2}$ over Kanpur and Gandhi College. ARF at the surface is $\geq-30$ W m$^{-2}$. Atmospheric warming is maximum during premonsoon (>30 W m$^{-2}$). Shortwave atmospheric heating due to aerosols is >0.4 K/day over IGP and peaks during premonsoon at >0.6 K/day due to lower single scattering albedo (SSA) and higher surface albedo. TOA forcing is always less negative over Kanpur when compared to Gandhi College due to lower surface albedo except in postmonsoon owing to higher SSA. This happens as TOA forcing depends on SSA and surface albedo in addition to aerosol optical depth. The magnitude of longwave forcing and atmospheric cooling in an absolute sense is significantly small and contributes only about 20% or less to the net (shortwave + longwave) forcing. Aerosol radiative effects over these two locations, despite differences in aerosol characteristics, are similar, thus confirming that aerosols and their radiative influence get transported due to circulation. ARF over Kanpur and Gandhi College is an order of magnitude higher when compared to greenhouse gas forcing. A large reduction in surface reaching solar irradiance accompanied by large atmospheric warming can have implications on precipitation and hydrological cycle, and these aerosol radiative effects should be included while performing regional-scale aerosol climate assessments.

Keywords Indo-Gangetic plain · Aerosol forcing · Shortwave · Longwave · Urban vs. Rural · Seasonal · Variations · Comparison

1 Introduction

Aerosols are a major atmospheric (ATM) component and influence the transfer of radiative energy and the conversion of water vapor into cloud droplets and raindrops. Despite the worldwide attention and several studies on the radiative effects of aerosols, they remain one of the largest sources of uncertainty in estimating climate forcing (Solomon et al. 2007). The uncertainty in aerosol radiative effects mainly arises due to the lack of reliable measurements on the spatial and temporal distribution of aerosols. The sources of aerosols include natural and anthropogenic and possess distinct characteristics and size distributions. The fine mode aerosols over urban, industrialized and densely populated regions arise mostly from gas to particle conversion and combustion which are mainly anthropogenic, while coarse mode aerosols such as wind-blown mineral dust and sea salt particles originate from

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