Wintertime aerosol properties during foggy and nonfoggy days over urban center Delhi and their implications for shortwave radiative forcing

Dilip Ganguly, A. Jayaraman, T. A. Rajesh, and H. Gadhavi

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We present results from complimentary measurements of physical and optical properties of aerosols carried out at Delhi, as part of the Indian Space Research Organization Geosphere Biosphere Programme’s Land Campaign II in December 2004. For the first time we unravel ground truth values of several radiatively important aerosol parameters such as their wavelength dependency in absorption, scattering behavior, single-scattering albedo, number size distribution, and vertical distribution in the atmosphere from this polluted megacity in south Asia. Interesting features are observed in the behavior of aerosol parameters under intermittent foggy, hazy, and clear-sky conditions prevalent during the campaign. All aerosol parameters exhibited a large distribution in their values, with variabilities being particularly higher on hazy and foggy days. The average clear-sky aerosol optical depth (AOD) value is 0.91 ± 0.48, which is higher than the AOD value reported for most other cities in India during this season of the year. Increases in AOD on hazy and foggy days are found to be spectrally nonuniform. The percentage increase in AOD at shorter wavelengths was higher on hazy days compared to clear days. Diurnally averaged BC mass concentration varied from a low of 15 \( \mu g/m^3 \) during clear days to a high of about 65 \( \mu g/m^3 \) on hazy days. The wavelength dependency of aerosol absorption shows signatures of the presence of a significant amount of absorbing aerosols produced from biofuel/biomass burning. Single-scattering albedo at 525 nm is found to vary between 0.6 and 0.8 with an average value of 0.68 for the entire period. Lidar observations reveal that during a fog event there is a subsidence of aerosols to an extremely dense and shallow atmospheric layer of less than 200 m height from the surface. The presence of an aerosol layer at elevated altitudes is also detected. All the results are combined and used for estimating aerosol radiative forcing using a discrete ordinate radiative transfer model. We find a large negative forcing at the surface level in the range of \(-40 \text{ to } -86 \text{ W/m}^2\), while forcing at the top of the atmosphere varied between \(-2 \text{ and } +3 \text{ W/m}^2\).


1. Introduction

Satellite data over northern India reveal persistent aerosol haze along the southern edge of Himalayan region and over the Indo-Gangetic plain extending across Bangladesh onto the Bay of Bengali during winter months (December to February), when there is minimal rainfall and a shallow boundary layer over this region [Kaufman et al., 2002]. This entire Indo-Gangetic belt is one of the densely populated areas of the globe and is a source region for various anthropogenic aerosols such as sulfates, nitrates, black carbons, etc. Over and above these prevailing hazy conditions, the situation becomes even worse at times when some of the areas within this region are affected by intense fog events. The high concentration of aerosols helps in the formation of early morning fog, which also turns into production of smog (smoke plus fog), causing severe reduction in visibility and leading to road accidents, health problems, delay in air traffic, etc. Since the fog droplets are formed on aerosols, which act as condensation nuclei, the onset of fog also depends on the properties of these aerosols [Pandis and Seinfeld, 1990], which also have an impact on the subsequent evolution of the fog layer. On the other hand, the presence of fog droplets can also modify the characteristics of aerosols by aqueous-phase chemical reactions occurring within the fog droplets as well as resulting in their removal from the atmosphere by wet deposition.