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Aerosol Direct Radiative Forcing over Delhi NCR, India: Sensitivity to Mixing State and Particle Shape

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Aerosol properties changes with the change in mixing state of aerosols and thus aerosol direct radiative forcing (DRF). The problem is important in the Indo-Gangetic Basin, Northern India, where various aerosol types mix and show strong seasonal variations. A detailed chemical composition analysis of aerosols for Delhi National capital region (NCR) is carried out during 2007-2008. These results were used to examine the sensitivity of optical properties to the aerosol mixing state. Black carbon, BC was measured directly by Aethalometer. The species are grouped into four major components; dust, water soluble (WS), water insoluble (WINS) and BC. To infer the probable mixing state of aerosols in the Delhi NCR, eight different mixing cases, external mixing, internal mixing, and six combinations of core- shell type mixing which includes two modes of dust (accumulation and coarse) have been considered. Core-shell mixing cases are considered to be as follows - BC over dust, WS over dust, BC over WS and, WS over BC. These core shell mixed components are then externally mixed with rest of the aerosol species. The spectral aerosol optical properties - extinction coefficient, single scattering albedo (SSA) and asymmetry parameter (g) for each of the mixing state cases are calculated. These optical properties are utilized to estimate the radiative forcing using a radiative transfer model. The surface-reaching fluxes for each of the cases are compared with MERRA downward shortwave surface flux. MISR aerosol products were also analyzed to understand the seasonal variations of the bulk aerosol properties that may help in interpreting the sensitivity results. We observed that for the pre-monsoon season (MAMJ), core shell mixed case; BC coated over WS (surface DRF is -10.52 Wm-2) and BC over coarse dust (surface DRF is -2.81 Wm-2) are the most probable mixing states. For monsoon season (JAS,) BC coated over coarse dust (often referred to as polluted dust) (surface DRF is -0.60 Wm-2) is in better agreement with MERRA. For the post-monsoon season (ON) and winter season (DJF); external and internal mixing states are comparatively closer to MERRA flux. The remaining discrepancy may be attributed to the assumption of uniform vertical distribution (calculated from CALIPSO data) for each individual aerosol species, whereas ideally different vertical profile should be considered. Secondly, dust is assumed to be spherical whereas literature suggests it to be non-spherical. Three non-spherical shapes - spheroid, cylinder and chebyshev are considered. We have calculated optical properties of dust assuming it to be non-spherical for all the three different shapes. Our results show that the SSA deviates from spherical dust case by $\sim$55% for all the three shapes, while the corresponding deviations for g are 15% for spheroid and cylinder shape and 38% for chebyshev shape. The % deviation of the externally mixed aerosol surface flux from non- spherical to spherical dust is in the range of 2-10%. Thus we observe that the absorption is under estimated at the surface if non-sphericity is not included in forcing estimation. The results will help reducing the uncertainty in aerosol DRF estimates for the Indian region.