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Aerosol Direct Radiative Forcing Over the Indian Subcontinent: A Comparative Analysis from the Satellite Observation and Radiative Transfer Model

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Abstract : Aerosol direct radiative forcing (ADRF) refers to the alteration of the Earth's energy balance from the scattering and absorption of solar radiation by aerosol particles. India experiences substantial ADRF due to high aerosol loading from various sources. These aerosols' radiative impact depends on their physical characteristics (such as size, shape, and composition) and atmospheric distribution. Quantifying ADRF is crucial for understanding aerosols' impact on the regional climate and the Earth's radiative budget. In this study, we have taken radiation data from Clouds and the Earth's Radiant Energy System (CERES, spatial resolution=1ox1o) for 22 years (2000-2021) over the Indian subcontinent. Except for a few locations, the short-wave DARF exhibits aerosol cooling at the TOA (values ranging from +2.5 W/m2 to -22.5W/m2). Cooling due to aerosols is more pronounced in the absence of clouds. Being an aerosol hotspot, higher negative ADRF is observed over the Indo-Gangetic Plain (IGP). Aerosol Forcing Efficiency (AFE) shows a decreasing seasonal trend in winter (DJF) over the entire study region while an increasing trend over IGP and western south India during the post-monsoon season (SON) in clear-sky conditions. Analysing atmospheric heating and AOD trends, we found that only the aerosol loading is not governing the change in atmospheric heating but also the aerosol composition and/or their vertical profile. We used a Multi-angle Imaging Spectro-Radiometer (MISR) Level-2 Version 23 aerosol products to look into aerosol composition. MISR incorporates 74 aerosol mixtures in its retrieval algorithm based on size, shape, and absorbing properties. This aerosol mixture information was used for analysing long-term changes in aerosol composition and dominating aerosol species corresponding to the aerosol forcing value. Further, ADRF derived from this method is compared with around 35 studies across India, where a plane parallel Radiative transfer model was used, and the model inputs were taken from the OPAC (Optical Properties of Aerosols and Clouds) utilizing only limited aerosol parameter measurements. The result shows a large overestimation of TOA warming by the latter (i.e., Model-based method).

Keywords : aerosol radiative forcing (ARF), aerosol composition, MISR, CERES, SBDART
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