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Evaluation of the MERRA-2 $PM_{2.5}$ mass and its constituent chemical species concentrations over a COALESCE network site in Bhopal, India

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Modern-Era Retrospective analysis for Research and Applications (MERRA-2) generated $PM_{2.5}$ concentrations are widely used to understand the spatio-temporal variability of $PM_{2.5}$ across the globe. Only $PM_{2.5}$ data from black carbon, organic carbon, sulphate, sea-salt, and dust are provided by MERRA-2. However, previous studies validated MERRA-2 $PM_{2.5}$ concentrations obtained by combining all five species data against in-situ total $PM_{2.5}$ concentrations. To the best of our knowledge, this is the first study over India to validate MERRA-2 species wise PM2.5 concentrations utilizing in-situ surface measurements made over a site at Bhopal (23.285° N, 22.277° E). Bhopal is one of the eleven COALESCE (Carbonaceous Aerosol Emissions, Source Apportionment and Climate Impacts) network regionally representative sites in India. 24 hour integrated filter-based samples (N = 165) collected during 2019, using the MetOne SASS® speciation sampler were used to measure mass and aerosol species concentrations by a variety of analyses. Our results show that the MERRA-2 well captures the aerosol species data at Bhopal. However, MERRA-2 underestimated the annual mean in-situ concentration of organic carbon, black carbon, and sulphate by 1.9 μg m^{-3} (~22 %), 1.3 μg m^{-3} (~47 %) and 0.9 μg m^{-3} (~11 %), respectively and overestimated the sea salt and dust components by 0.75 μg m^{-3} (~95 %) and 8.5 μg m^{-3} (~153 %), respectively. It is pertinent to note that dust from surface aerosol chemical species measurements was re-constructed using elemental aluminium, silicon, potassium, calcium, titanium, manganese concentrations. Further, the annual mean MERRA-2 $PM_{2.5}$ mass (reconstructed from its constituent species) underestimated the average in-situ $PM_{2.5}$ mass by 13.55 μg m^{-3} (~26.16 %). This underestimation is likely due to aerosol nitrate not being included in the MERRA2 $PM_{2.5}$ mass and uncertainties in aerosol species concentrations resulting from limitations in the chemical transport model set-up and emissions inventories. This study discusses the possible causes of disagreements between in-situ measurements and MERRA2 products, in addition to estimating the effect of including nitrate in the MERRA2 $PM_{2.5}$ mass reconstruction.