Inter- versus Intracity Variations in the Performance and Calibration of Low-Cost PM2.5 Sensors: A Multicity Assessment in India

Abstract

Low-cost sensors (LCSs) have revolutionized the air pollution monitoring landscape. However, the sensitivities of particulate matter (PM) LCS measurements to various particle microphysical properties and meteorological aspects warrant an accuracy investigation. We investigated the inter- and intracity variations in the accuracy of LCS-measured $PM_{2.5}$ across geographically and demographically distinct Indian cities. The collocation data of $PM_{2.5}$ (collected during March–April 2022) from an LCS (Atmos) and a reference-grade instrument (β attenuation monitor) from nine sites (across five cities) were analyzed. The root-mean-square error (RMSE) in the hourly mean raw (uncorrected) Atmos $PM_{2.5}$ measurements varied significantly across the cities. The Atmos $PM_{2.5}$ overestimated the reference-grade $PM_{2.5}$ values in cities located in the Indo-Gangetic Plain (Chandigarh and New Delhi) but considerably underestimated the values in the city located in western India (Mumbai). In south Indian cities (Bengaluru and Chennai), the Atmos $PM_{2.5}$ measurements were relatively close to the reference-grade $PM_{2.5}$ measurements. Among various statistical calibration models trained to correct the Atmos $PM_{2.5}$ measurements for most locations, a generalized additive model performed better than other models. The performance of the calibration models was investigated using the holdout cross-validation method. The correction models improved the accuracy of the Atmos $PM_{2.5}$ measurements by up to 70%. The bias range of the intracity (Mumbai) raw Atmos $PM_{2.5}$ measurements was approximately comparable to the intercity bias range. Across the study locations, the generalized additive model performed the best in correcting the raw LCS $PM_{2.5}$ measurements. We also demonstrated that the application of the location-specific calibration model to correct Atmos $PM_{2.5}$ measurements improved the accuracy of the LCS $PM_{2.5}$ measurements compared with the application of a single-location calibration model for city-wide data.